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ONGERUBRICEERD

TNO-report

97-CMC-R0257   SHOCK TRIALS TROJKA DRONE;
                MEASUREMENTS SHOT 4, 5 and 6

TNO Building and
Construction Research   DTIC QUALITY INSPECTED 4

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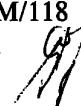
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Managementuittreksel

Titel	:	UNDEX SHOCK TRIALS TROJKA DRONE;
		MEASUREMENTS SHOT 4, 5 and 6
Auteur	:	ing. B. Bosman
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Mijnenbestrijdingsoperaties met de op afstand bestuurde Trojka drones vereisen een grote schokbestendigheid van deze schepen.

Een eerste serie van drie schokproeven met onderwater explosies vond in augustus 1996 plaats, een tweede serie van drie schokproeven in oktober 1996. Daarbij werd een 16 m lange beballaste proefromp, met daarin opgesteld een zwevende vloer, zwaar op schok belast.

Het doel van deze proefnemingen is om duidelijker de grenzen van de operationele inzetbaarheid te kunnen aangeven en over meer gegevens te kunnen beschikken betreffende de optredende schokbewegingen. Die moeten dan vertaald worden naar het Schokbestek voor Trojka.

In opdracht van de Afdeling Scheepsbouw, Bureau SO&O, heeft TNO met ruim 50 meetkanalen versnellingen, rekken, relatieve verplaatsingen en drukken vastgelegd.

De eerste serie van drie schokproeven zijn gerapporteerd in TNO-rapport 96-CMC-R0294. Dit rapport beschrijft de tweede serie van drie schokproeven en presenteert alleen de meetsignalen.

In het kader van een andere opdracht (A96/KM/147) is inmiddels begonnen met de interpretatie van die meetsignalen en de betreffende rapportage.

Contents

1.   Introduction

The Royal Netherlands Navy started a research project for modernizing the mine sweeping capabilities.
A part of the project investigates the possibilities to use a system of mine sweeping drones which are unmanned and remotely operated, called Trojka system.
Because the Trojka system will be exposed to severe underwater explosion shock loadings, extreme high demands were set with respect to shock resistance.
In order to investigate the behaviour of the Trojka structure against shock load, underwater shock load tests were carried out on a full scale test model of the Trojka vessel.

The project is done in close cooperation with the Wehrtechnische Dienststelle für Schiffe und Marinewaffen (WTD71).
The first series of three measurements have been carried out near Eckernförde, Germany. WTD71 did additional measurements as laser displacements, pressure transducers and accelerometers.
The second series of three measurements have been carried out at the Northsee. WTD71 did additional measurements as laser displacements (for shot 4) and pressure transducers. This report only contains the measured results of TNO for shot 4 to 6.
The first series of three measurements (shot 1 to 3) are reported in TNO-report 96-CMC-R0294 [1].
The strain gauges were mounted by the 'Marine Electronisch en Optisch Bedrijf'(MEOB) as well as the cabling inside the drone. The measuring cables from drone to measuring ship were provided with connectors by the MEOB.

2.   Objectives

The objectives of the tests is to assess the resistance of the structure to underwater shock loads and to assess the response of the drone and the floating deck due to the bulk cavitation closure pulse and to the gasbubble pulsation.

The shock behaviour will be described in a future interpretation report and will be used for the shock specifications of the Trojka drones.

3.   Experimental setup and measurement system

3.1   Test setup

The test setup, charge geometry and resulting damage are described in a separate report of the Royal Netherlands Navy [2].

3.2   Measurement locations

The following transducers have been used :
- a trigger signal device;
- the detonation signal device;
- 24 strain gauges;
- 4 relative displacement transducers;
- 28 accelerometers;
- 2 pressure transducers.

The transducers are indicated as follows :
S: strain gauge;
A: accelerometer;
R: relative displacement transducer between shell and floating deck;
P: pressure transducer in the water.

Definition of Drone sections :
1: aft compartment;
2: engine room;
3: fuel tank;
4: fore compartment.

Definition of the axes :
0-point all axes   : centre of aft bulkhead, outside;
+x axis   : from 0-point to bowsection;
+y axis   : from 0-point to P.S;
+z axis   : from 0-point up.

Table 1 gives the coordinates of the transducers.
The position of the transducers are graphically presented in figure 1.

3.3   Data acquisition system and signal conditioning

All used accelerometers and the pressure transducer are piezo resistive because this type of transducers gives the best results on shock.

Accelerometers A1 to A16 have been mounted using a so-called mechanical filter (an aluminium-rubber interface) [3]. For these locations undamped accelerometers of Endevco type 7270A-6K (range 6,000 g) and 7270A-20K (range 20,000 g) have been used.

Accelerometers A17 to A28 are mounted on the floating deck. Internally damped accelerometers of Endevco type 2262A-200 (range 200 g) have been used (for shot 5 and shot 6 at location A17 and at location A22 accelerometers of Endevco type 7270A-6K have been used).

The transducers have been calibrated prior to testing and checked afterwards again. The acquisition equipment is calibrated regularly.

For signal conditioning and acquisition a 58 channel SCADAS-II system equipped with PDFA-ETD modules (make Difa) was used.

The sampling frequency is 16129 Hz.

To make a higher sample rate possible a 16 channel DSA210 (make Difa) has been used with a sampling frequency of 51200 Hz.

The trigger signal, detonation signal, A1 to A3, A5, A7 to A11, A13, A15, A16, P1 and P2 have been measured with a sampling frequency of 51200 Hz.

All the measuring systems used, operated with a 16 bits ADC and the analogue low pass filters are optimized for linear phase characteristic to ensure an undistorted time history.

3.4   Calibration of accelerometers

All accelerometers were calibrated according to ISO 5347 part 3, using a shaker and a primary standard accelerometer.

The type 7270A-6K and 7270A-20K accelerometers were supplementary calibrated on shock, using a Hopkinson bar and a laser displacement sensor as a reference.

In order to get information about the reliability of the double integrated acceleration signals some measurements were done using the Hopkinson bar.

It is found that the 7270A-20K accelerometers give good displacement results over a timeperiod between 10 and 25 ms (the mean timeperiod of valid displacement signals is 22 ms). The 7270A-6K accelerometers give good displacement results over a timeperiod between 20 and 30 ms (the mean timeperiod of valid displacement signals is 26 ms). The length of the valid part depends mainly on the transducer itself.

For the 2262A-200 accelerometers a double integration over 500 ms is normally no problem.

3.5   Calibration of pressure transducer

A static calibration of the pressure transducers have been carried out using a primary standard.

The pressure transducers were tested dynamically using a special water tube in which the actual shock signal is simulated.

4.   Results

Already before shot 4 strain gauge S9 and strain gauge S10 were not working. There was no opportunity to repair these strain gauges.
At shot 4 accelerometers A1, A7 and A15 failed. Accelerometer A15 could be replaced by another transducer, A1 and A7 could not be repaired.

The acceleration signals have been integrated in time in order to obtain absolute velocities. The zero level, as measured, is corrected prior to time integration by adding a scalar (taking into account the threshold of the accelerometer). No further adjustments have been made to make a good interpretation possible.
The integrated accelerations were integrated in time again in order to obtain absolute displacements.
The integrator used, operates by the trapezium algorithm.
Difficulties with the integration occurs when there is a high noise level in the acceleration signal and/or when the signals are disturbed, for instance by connector problems.
The maximax shock response spectra were calculated from the acceleration signals at 1 % damping with 24 points per octave.

The nature of the signal depends on the location. On the floating deck for instance the signals are much slower. The duration of the presented signals were choosen as good as possible in agreement with the nature of the signals.
Table 2 gives an overview of the presented figures of shot 4, table 3 gives an overview of the presented figures of shot 5 and table 4 gives an overview of the presented figures of shot 6.

Time 0 is the detonation time.
All accelerometer signals are positive in the positive direction of the axes in which direction they are mounted. (The definition of the axes are given in chapter 3.2)
The relative displacement transducers R1 to R4 gives a negative signal due to shortening.
The floating deck moves much more vertically than horizontally so the signals of R2 and R4 will not purely be the horizontal movements (They are influenced by the vertical movements).

From some sensors there were small DC-shifts and spikes in the time signals. Those disturbances are typically for cabling problems and connection problems.
During the first series of three measurements (shot 1 to 3) it was found that the connectors of the long measuring cable give problems when these are hit in transverse direction. [1]
There was no opportunity to provide the measuring cables with other connectors.

During shot 4 accelerometers A25 to A28 were not mounted.
From the integrated signals of A3, A4 and A12 it is clear that these signals are disturbed. The disturbances are probably caused by connector problems.
Of course the result of the maximax shock response spectra calculation is influenced as well

by disturbances of the time histories.
The signal of A3 is only valid for about 15 ms and A12 is only valid for about 2.54 ms.
From the signal of A12 no shock response spectrum is calculated.
The shock response spectrum of A3 is calculated only over the first 15 ms signal.

During shot 5 accelerometers A3, A4, A18 to A21, A23 and A24 were not mounted.
There still were some connector problems.
Integration of A10 to A12 and A16 shows that these signals are disturbed.
The results of the maximax shock response spectra calculations are influenced by these disturbances.
The signal of A12 is only valid for about 5 ms and A16 is only valid for about 6.1 ms.
From the signals of A10 to A12 and A16 no shock response spectrum is calculated.
The relative displacements of R1 and R3 failed.

During shot 6 accelerometers A3, A4, A18 to A21, A23 and A24 were not mounted.
There still were some connector problems.
Integration of A2, A10 to A13 and A16 shows that these signals are disturbed.
The results of the maximax shock response spectra calculations are influenced by these disturbances.
The signal of A2 is only valid for about 5 ms, A13 is only valid for about 3.5 ms and A16 is only valid for about 4.4 ms.
From the signals of A2, A13 and A16 no shock response spectrum is calculated.
The relative displacements (R1 to R4) failed after about 820 ms signal.
The pressure transducer P1 changed from position during shot 6. It moved up about 2 meters. This is probably caused by the gas bubble.

A final remark concerns the specific mentioning in the foregoing text of those acceleration signals being disturbed during the various shots. Contemplating these signals after integration (velocity results), it is quite clear from the signals themselves that they are showing defects.
Note that there are other acceleration signals, not mentioned before, which suffer to some extend from these disturbances as well.
Only the transducers on shell, foundation and bulkheads (A1 to A16) show such limitations.

Acknowledgement

The Centre for Mechanical Engineering, part of TNO Building and Construction Research, thanks the 'Wehrtechnische Dienststelle für Schiffe und Marinewaffen' and the 'Marine Electronisch en Optisch Bedrijf' for the very good and pleasant cooperation.

Literature

[1]   B. Bosman; Shock trials trojka drone; measurements shot 1, 2 and 3.
        TNO-report 96-CMC-R0294, 2 august 1996

[2]   Report describing the test setup, charge geometry and damage by the Royal
        Netherlands Navy, to be issued.

[3]   B. Bosman; Mechanical filter
        Memorandum 95-CMC-M149, 1995

Table 1. Sensor locations

sensor	section	global position	x[mm]	y[mm]	z[mm]
S1	1	top deck, outside	3500	0	1550
S2	1	top deck, inside	3500	0	1525
S3	2	shell outside, on waterline	8000	-1550	0
S4	2	shell inside, on waterline	8000	-1525	0
S5	2	shell outside, near foundation	7900	-1110	-1120
S6	2	shell outside, near foundation	7900	-1110	-1120
S7	2	shell inside, near foundation	7900	-1090	-1100
S8	2	shell inside, near foundation	7900	-1090	-1100
S9	2	shell outside, near foundation	7900	-910	-1290
S10	2	shell outside, near foundation	7900	-910	-1290
S11	2	shell inside, near foundation	7900	-890	-1260
S12	2	shell inside, near foundation	7900	-890	-1260
S13	2	shell outside, between keel and foundation	7900	-480	-1500
S14	2	shell outside, between keel and foundation	7900	-480	-1500
S15	2	shell inside, between keel and foundation	7900	-470	-1470
S16	2	shell inside, between keel and foundation	7900	-470	-1470
S17	2	shell outside, keel	7900	0	-1550
S18	2	shell outside, keel	7900	0	-1550
S19	2	shell inside, keel	7900	0	-1525
S20	2	shell inside, keel	7900	0	-1525
S21	2	shell outside, near foundation	7900	1110	-1120
S22	2	shell outside, near foundation	7900	1110	-1120
S23	2	shell inside, near foundation	7900	1090	-1100
S24	2	shell inside, near foundation	7900	1090	-1100
S25	4	top deck, outside	13500	0	1550
S26	4	top deck, inside	13500	0	1525
A1	1	aft bulkhead, near keel	25	0	-1400
A2	1	aft bulkhead, near top deck	25	0	1400
A3	2	aft bulkhead engine room, near keel	6010	0	-1400
A4	2	aft bulkhead engine room, near keel	6010	0	-1400
A5	2	aft bulkhead engine room, near top deck	6010	-100	1400

sensor	section	global position	x[mm]	y[mm]	z[mm]
A6	2	aft bulkhead engine room, near top deck	6010	-100	1400
A7	2	shell, near foundation	8100	1120	-1050
A8	2	on the foundation	8100	1040	-1110
A9	2	shell, near foundation	8100	-1120	-1050
A10	2	on the foundation	8100	-1040	-1110
A11	2	fore bulkhead engine room, near keel	9990	0	-1400
A12	2	fore bulkhead engine room, near keel	9990	0	-1400
A13	2	fore bulkhead engine room, near top deck.	9990	0	1400
A14	2	fore bulkhead engine room, near top deck.	9990	0	1400
A15	4	fore bulkead, near keel	15975	0	-1205
A16	4	fore bulkead, near top deck	15975	0	1400
A17	2	floating deck	8090	900	-700
A18	2	floating deck	8090	900	-700
A19	2	dummy mass floating deck	8090	300	0
A20	2	top dummy mass floating deck	8090	0	725
A21	2	top dummy mass floating deck	8090	0	725
A22	2	floating deck	8090	-900	-700
A23	2	floating deck aft	6620	0	-700
A24	2	floating deck fore	9560	0	-700
A25	2	top dummy mass floating deck	9040	0	725
A26	2	top dummy mass floating deck	9040	0	725
A27	2	top dummy mass floating deck	7170	0	725
A28	2	top dummy mass floating deck	7170	0	725
R1	2	between shell and f.d.	8090	1375*	-675*
R2	2	between shell and f.d.	8090	1375*	-675*
R3	2	between shell and f.d.	8090	-1375*	-675*
R4	2	between shell and f.d.	8090	-1375*	-675*
P1	-	8 m. below waterline, PS	8000	1550	-8000
P2	-	4 m. below waterline, PS	8000	1550	-4000

* attachment point on the shell

Table 2. Presented figures for shot 4

Sensor	SHOT 4 figure number (presented time in ms)									SRS 1-1000 Hz
	10-30	15-35	10-100	0-240	0-300	0-500	0-1000	0-1400	0-1600	
P1	2	-	-	-	-	-	4	-	-	-
P2	3						5			
S1	-	30	-	-	6	-	-	-	-	-
S2	-	31	-	-	7	-	-	-	-	-
S3	-	32	-	-	8	-	-	-	-	-
S4	-	33	-	-	9	-	-	-	-	-
S5	-	34	-	-	10	-	-	-	-	-
S6	-	35	-	-	11	-	-	-	-	-
S7	-	36	-	-	12	-	-	-	-	-
S8	-	37	-	-	13	-	-	-	-	-
S11	-	38	-	-	14	-	-	-	-	-
S12	-	39	-	-	15	-	-	-	-	-
S13	-	40	-	-	16	-	-	-	-	-
S14	-	41	-	-	17	-	-	-	-	-
S15	-	42	-	-	18	-	-	-	-	-
S16	-	43	-	-	19	-	-	-	-	-
S17	-	44	-	-	20	-	-	-	-	-
S18	-	45	-	-	21	-	-	-	-	-
S19	-	46	-	-	22	-	-	-	-	-
S20	-	47	-	-	23	-	-	-	-	-
S21	-	48	-	-	24	-	-	-	-	-
S22	-	49	-	-	25	-	-	-	-	-
S23	-	50	-	-	26	-	-	-	-	-
S24	-	51	-	-	27	-	-	-	-	-
S25	-	52	-	-	28	-	-	-	-	-
S26	-	53	-	-	29	-	-	-	-	-
A2	-	-	-	54	-	-	-	-	-	117
A3	-	-	-	55	-	-	-	-	-	118
A4	-	-	-	56	-	-	-	-	-	119
A5	-	-	-	57	-	-	-	-	-	120
A6	-	-	-	58	-	-	-	-	-	121

Sensor	SHOT 4 figure number (presented time in ms)									SRS 1-1000 Hz
	10-30	15-35	10-100	0-240	0-300	0-500	0-1000	0-1400	0-1600	
A8	-	-	-	59	-	-	-	-	-	122
A9	-	-	-	60	-	-	-	-	-	123
A10	-	-	-	61	-	-	-	-	-	124
A11	-	-	-	62	-	-	-	-	-	125
A12	-	-	-	63	-	-	-	-	-	-
A13	-	-	-	64	-	-	-	-	-	126
A14	-	-	-	65	-	-	-	-	-	127
A16	-	-	-	66	-	-	-	-	-	128
A17	-	-	-	-	-	-	-	-	67	129
A18	-	-	-	-	-	-	-	-	68	130
A19	-	-	-	-	-	-	-	-	69	131
A20	-	-	-	-	-	-	-	-	70	132
A21	-	-	-	-	-	-	-	-	71	133
A22	-	-	-	-	-	-	-	-	72	134
A23	-	-	-	-	-	-	-	-	73	135
A24	-	-	-	-	-	-	-	-	74	136
vel. A2	-	-	75	-	-	-	-	-	-	-
vel. A3	-	-	76	-	-	-	-	-	-	-
vel. A4	-	-	77	-	-	-	-	-	-	-
vel. A5	-	-	78	-	-	-	-	-	-	-
vel. A6	-	-	79	-	-	-	-	-	-	-
vel. A8	-	-	80	-	-	-	-	-	-	-
vel. A9	-	-	81	-	-	-	-	-	-	-
vel. A10	-	-	82	-	-	-	-	-	-	-
vel. A11	-	-	83	-	-	-	-	-	-	-
vel. A12	-	-	84	-	-	-	-	-	-	-
vel. A13	-	-	85	-	-	-	-	-	-	-
vel. A14	-	-	86	-	-	-	-	-	-	-
vel. A16	-	-	87	-	-	-	-	-	-	-
vel. A17	-	-	-	-	-	88	-	-	-	-
vel. A18	-	-	-	-	-	89	-	-	-	-
vel. A19	-	-	-	-	-	90	-	-	-	-

Sensor	SHOT 4 figure number (presented time in ms)									SRS 1-1000 Hz
	10-30	15-35	10-100	0-240	0-300	0-500	0-1000	0-1400	0-1600	
vel. A20	-	-	-	-	-	91	-	-	-	-
vel. A21	-	-	-	-	-	92	-	-	-	-
vel. A22	-	-	-	-	-	93	-	-	-	-
vel. A23	-	-	-	-	-	94	-	-	-	-
vel. A24	-	-	-	-	-	95	-	-	-	-
displ. A2	-	-	96	-	-	-	-	-	-	-
displ. A3	-	-	97	-	-	-	-	-	-	-
displ. A4	-	-	98	-	-	-	-	-	-	-
displ. A5	-	-	99	-	-	-	-	-	-	-
displ. A6	-	-	100	-	-	-	-	-	-	-
displ. A8	-	-	101	-	-	-	-	-	-	-
displ. A9	-	-	102	-	-	-	-	-	-	-
displ. A10	-	-	103	-	-	-	-	-	-	-
displ. A11	-	-	104	-	-	-	-	-	-	-
displ. A12	-	-	105	-	-	-	-	-	-	-
displ. A13	-	-	106	-	-	-	-	-	-	-
displ. A14	-	-	107	-	-	-	-	-	-	-
displ. A16	-	-	108	-	-	-	-	-	-	-
displ. A17	-	-	-	-	-	109	-	-	-	-
displ. A18	-	-	-	-	-	110	-	-	-	-
displ. A19	-	-	-	-	-	111	-	-	-	-
displ. A20	-	-	-	-	-	112	-	-	-	-
displ. A21	-	-	-	-	-	113	-	-	-	-
displ. A22	-	-	-	-	-	114	-	-	-	-
displ. A23	-	-	-	-	-	115	-	-	-	-
displ. A24	-	-	-	-	-	116	-	-	-	-
rel.displ. R1	-	-	-	-	141	-	-	137		-
rel.displ. R2	-	-	-	-	142	-	-	138		-
rel.displ. R3	-	-	-	-	143	-	-	139		-
rel.displ. R4	-	-	-	-	144	-	-	140		-

Table 3. Presented figures for shot 5

Sensor	SHOT 5 figure number (presented time in ms)							SRS
	8-28	12-32	10-100	0-240	0-300	0-2000	0-4000	1-1000 Hz
P1	145	-	-	-	-	-	146/147	-
S1	-	172	-	-	148	-	-	-
S2	-	173	-	-	149	-	-	-
S3	-	174	-	-	150	-	-	-
S4	-	175	-	-	151	-	-	-
S5	-	176	-	-	152	-	-	-
S6	-	177	-	-	153	-	-	-
S7	-	178	-	-	154	-	-	-
S8	-	179	-	-	155	-	-	-
S11	-	180	-	-	156	-	-	-
S12	-	181	-	-	157	-	-	-
S13	-	182	-	-	158	-	-	-
S14	-	183	-	-	159	-	-	-
S15	-	184	-	-	160	-	-	-
S16	-	185	-	-	161	-	-	-
S17	-	186	-	-	162	-	-	-
S18	-	187	-	-	163	-	-	-
S19	-	188	-	-	164	-	-	-
S20	-	189	-	-	165	-	-	-
S21	-	190	-	-	166	-	-	-
S22	-	191	-	-	167	-	-	-
S23	-	192	-	-	168	-	-	-
S24	-	193	-	-	169	-	-	-
S25	-	194	-	-	170	-	-	-
S26	-	195	-	-	171	-	-	-
A2	-	-	-	196	-	-	-	248
A5	-	-	-	197	-	-	-	249
A6	-	-	-	198	-	-	-	250
A8	-	-	-	199	-	-	-	251
A9	-	-	-	200	-	-	-	252
A10	-	-	-	201	-	-	-	-

Sensor	SHOT 5 figure number (presented time in ms)							SRS 1-1000 Hz
	8-28	12-32	10-100	0-240	0-300	0-2000	0-4000	
A11	-	-	-	202	-	-	-	-
A12	-	-	-	203	-	-	-	-
A13	-	-	-	204	-	-	-	253
A14	-	-	-	205	-	-	-	254
A15	-	-	-	206	-	-	-	255
A16	-	-	-	207	-	-	-	-
A17	-	-	-	208	-	-	-	256
A22	-	-	-	209	-	-	-	257
A25	-	-	-	-	-	210	-	258
A26	-	-	-	-	-	211	-	259
A27	-	-	-	-	-	212	-	260
A28	-	-	-	-	-	213	-	261
vel. A2	-	-	214	-	-	-	-	-
vel. A5	-	-	215	-	-	-	-	-
vel. A6	-	-	216	-	-	-	-	-
vel. A8	-	-	217	-	-	-	-	-
vel. A9	-	-	218	-	-	-	-	-
vel. A12	-	-	219	-	-	-	-	-
vel. A13	-	-	220	-	-	-	-	-
vel. A14	-	-	221	-	-	-	-	-
vel. A15	-	-	222	-	-	-	-	-
vel. A16	-	-	223	-	-	-	-	-
vel. A17	-	-	224	-	-	-	-	-
vel. A22	-	-	225	-	-	-	-	-
vel. A25	-	-	-	-	-	226	-	-
vel. A26	-	-	-	-	-	227	-	-
vel. A27	-	-	-	-	-	228	-	-
vel. A28	-	-	-	-	-	229	-	-
displ. A2	-	-	230	-	-	-	-	-
displ. A5	-	-	231	-	-	-	-	-
displ. A6	-	-	232	-	-	-	-	-
displ. A8	-	-	233	-	-	-	-	-

Sensor	SHOT 5 figure number (presented time in ms)							SRS
	8-28	12-32	10-100	0-240	0-300	0-2000	0-4000	1-1000 Hz
displ. A9	-	-	234	-	-	-	-	-
displ. A12	-	-	235	-	-	-	-	-
displ. A13	-	-	236	-	-	-	-	-
displ. A14	-	-	237	-	-	-	-	-
displ. A15	-	-	238	-	-	-	-	-
displ. A16	-	-	239	-	-	-	-	-
displ. A17	-	-	240	-	-	-	-	-
displ. A22	-	-	241	-	-	-	-	-
displ. A25	-	-	-	-	-	242/246	-	-
displ. A26	-	-	-	-	-	243/247	-	-
displ. A27	-	-	-	-	-	244/246	-	-
displ. A28	-	-	-	-	-	245/247	-	-
rel.displ. R2	-	-	-	-	264	262	-	-
rel.displ. R4	-	-	-	-	265	263	-	-

Table 4. Presented figures for shot 6

Sensor	SHOT 6 figure number (presented time in ms)									SRS 1-1000 Hz
	5-25	8-28	5-95	0-240	0-300	0-900	0-3000	0-4000	0-12000	
P1	266	-	-	-	-	-	267	268	-	-
S1	-	293	-	-	269	-	-	-	-	-
S2	-	294	-	-	270	-	-	-	-	-
S3	-	295	-	-	271	-	-	-	-	-
S4	-	296	-	-	272	-	-	-	-	-
S5	-	297	-	-	273	-	-	-	-	-
S6	-	298	-	-	274	-	-	-	-	-
S7	-	299	-	-	275	-	-	-	-	-
S8	-	300	-	-	276	-	-	-	-	-
S11	-	301	-	-	277	-	-	-	-	-
S12	-	302	-	-	278	-	-	-	-	-
S13	-	303	-	-	279	-	-	-	-	-
S14	-	304	-	-	280	-	-	-	-	-
S15	-	305	-	-	281	-	-	-	-	-
S16	-	306	-	-	282	-	-	-	-	-
S17	-	307	-	-	283	-	-	-	-	-
S18	-	308	-	-	284	-	-	-	-	-
S19	-	309	-	-	285	-	-	-	-	-
S20	-	310	-	-	286	-	-	-	-	-
S21	-	311	-	-	287	-	-	-	-	-
S22	-	312	-	-	288	-	-	-	-	-
S23	-	313	-	-	289	-	-	-	-	-
S24	-	314	-	-	290	-	-	-	-	-
S25	-	315	-	-	291	-	-	-	-	-
S26	-	316	-	-	292	-	-	-	-	-
A2	-	-	-	317	-	-	-	-	-	-
A5	-	-	-	318	-	-	-	-	-	373
A6	-	-	-	319	-	-	-	-	-	374
A8	-	-	-	320	-	-	-	-	-	375
A9	-	-	-	321	-	-	-	-	-	376
A10	-	-	-	322	-	-	-	-	-	377

Sensor	SHOT 6	figure number (presented time in ms)								SRS 1-1000 Hz
	5-25	8-28	5-95	0-240	0-300	0-900	0-3000	0-4000	0-12000	
A11	-	-	-	323	-	-	-	-	-	378
A12	-	-	-	324	-	-	-	-	-	379
A13	-	-	-	325	-	-	-	-	-	-
A14	-	-	-	326	-	-	-	-	-	380
A15	-	-	-	327	-	-	-	-	-	381
A16	-	-	-	328	-	-	-	-	-	-
A17	-	-	-	329	-	-	-	-	-	382
A22	-	-	-	330	-	-	-	-	-	383
A25	-	-	-	-	-	-	331	-	-	384
A26	-	-	-	-	-	-	332	-	-	385
A27	-	-	-	-	-	-	333	-	-	386
A28	-	-	-	-	-	-	334	-	-	387
vel. A2	-	-	335	-	-	-	-	-	-	-
vel. A5	-	-	336	-	-	-	-	-	-	-
vel. A6	-	-	337	-	-	-	-	-	-	-
vel. A8	-	-	338	-	-	-	-	-	-	-
vel. A9	-	-	339	-	-	-	-	-	-	-
vel. A10	-	-	340	-	-	-	-	-	-	-
vel. A11	-	-	341	-	-	-	-	-	-	-
vel. A12	-	-	342	-	-	-	-	-	-	-
vel. A13	-	-	343	-	-	-	-	-	-	-
vel. A14	-	-	344	-	-	-	-	-	-	-
vel. A15	-	-	345	-	-	-	-	-	-	-
vel. A16	-	-	346	-	-	-	-	-	-	-
vel. A17	-	-	347	-	-	-	-	-	-	-
vel. A22	-	-	348	-	-	-	-	-	-	-
vel. A25	-	-	-	-	-	-	349	-	-	-
vel. A26	-	-	-	-	-	-	350	-	-	-
vel. A27	-	-	-	-	-	-	351	-	-	-
vel. A28	-	-	-	-	-	-	352	-	-	-
displ. A2	-	-	353	-	-	-	-	-	-	-
displ. A5	-	-	354	-	-	-	-	-	-	-

Sensor	SHOT 6 figure number (presented time in ms)									SRS 1-1000 Hz
	5-25	8-28	5-95	0-240	0-300	0-900	0-3000	0-4000	0-12000	
displ. A6	-	-	355	-	-	-	-	-	-	-
displ. A8	-	-	356	-	-	-	-	-	-	-
displ. A9	-	-	357	-	-	-	-	-	-	-
displ. A10	-	-	358	-	-	-	-	-	-	-
displ. A11	-	-	359	-	-	-	-	-	-	-
displ. A12	-	-	360	-	-	-	-	-	-	-
displ. A13	-	-	361	-	-	-	-	-	-	-
displ. A14	-	-	362	-	-	-	-	-	-	-
displ. A15	-	-	363	-	-	-	-	-	-	-
displ. A16	-	-	364	-	-	-	-	-	-	-
displ. A17	-	-	365	-	-	-	-	-	-	-
displ. A22	-	-	366	-	-	-	-	-	-	-
displ. A25	-	-	-	-	-	-	367	-	371	-
displ. A26	-	-	-	-	-	-	368	-	372	-
displ. A27	-	-	-	-	-	-	369	-	373	-
displ. A28	-	-	-	-	-	-	370	-	374	-
rel.displ. R1	-	-	-	-	392	388	-	-		-
rel.displ. R2	-	-	-	-	393	389	-	-		-
rel.displ. R3	-	-	-	-	394	390	-	-		-
rel.displ. R4	-	-	-	-	395	391	-	-		-

TOPVIEW

SIDEVIEW

SECTION ON CL

A16 S26 S25 A25 A14 A13 A21 A ← A20 A19 A5 A6 S2 S1 A27

A15 A26 A11 A12 A24 A → A18 A17 A23 A4 A3 A28

SECTION ON WL

A12 A24 A22 A21 A4

A15 A11 A20 A19 A17 A18 A23 A3

BALLASTROOM
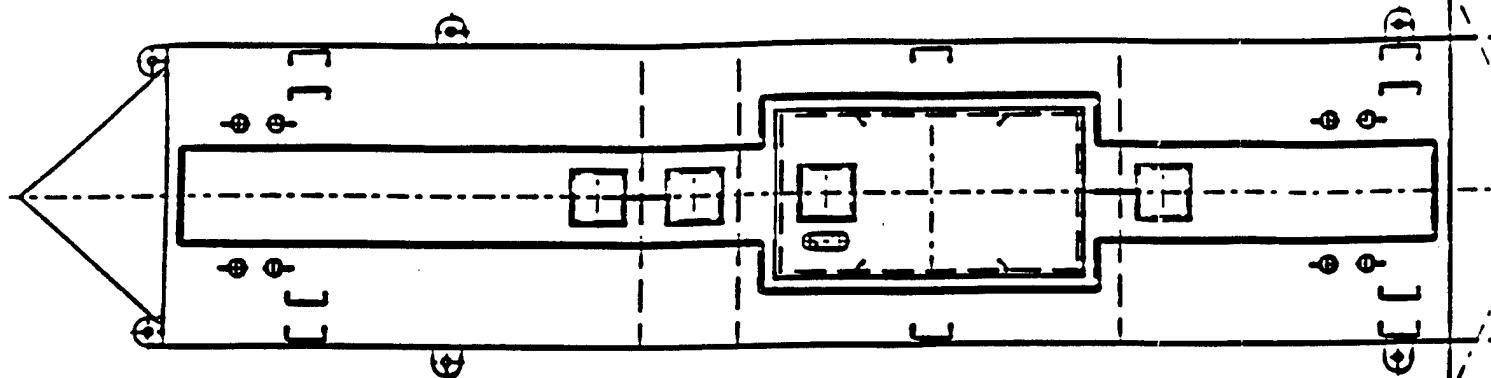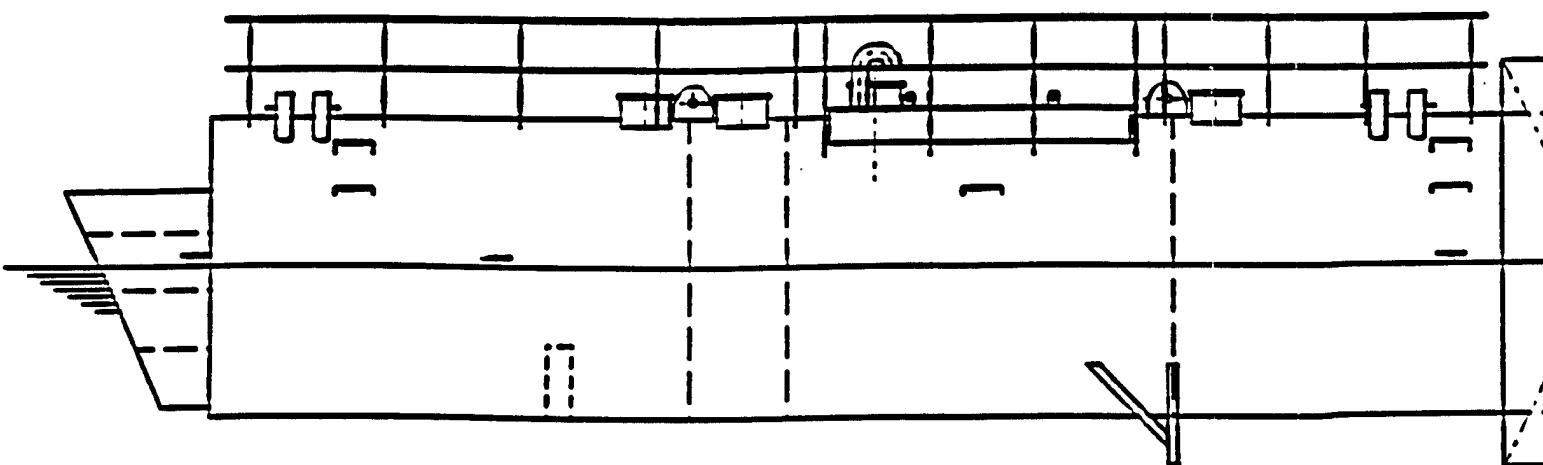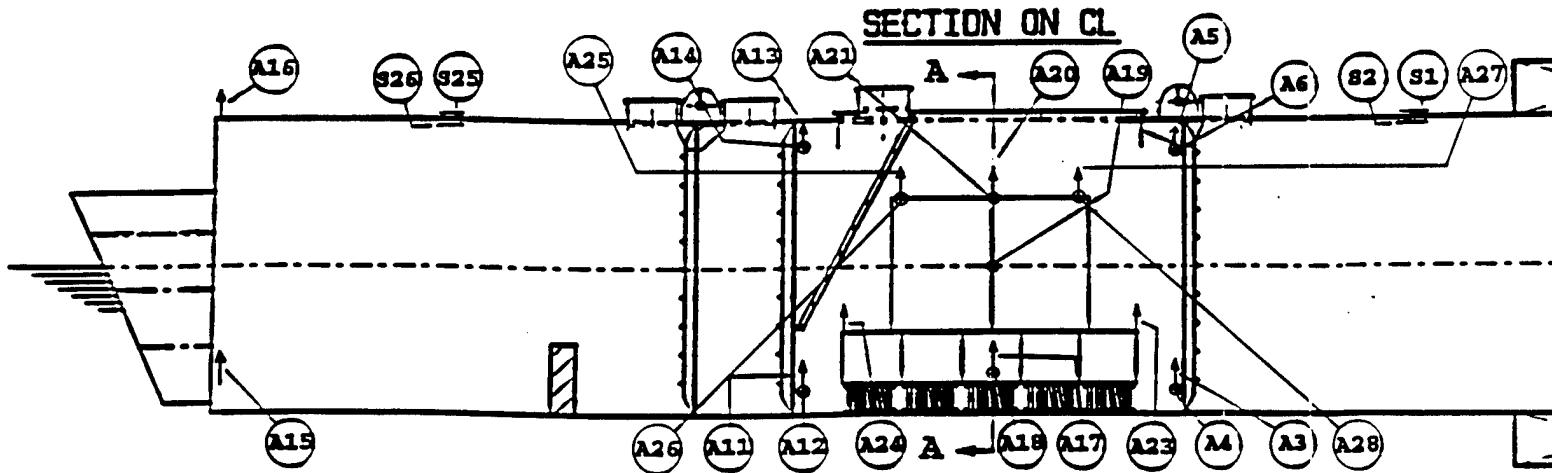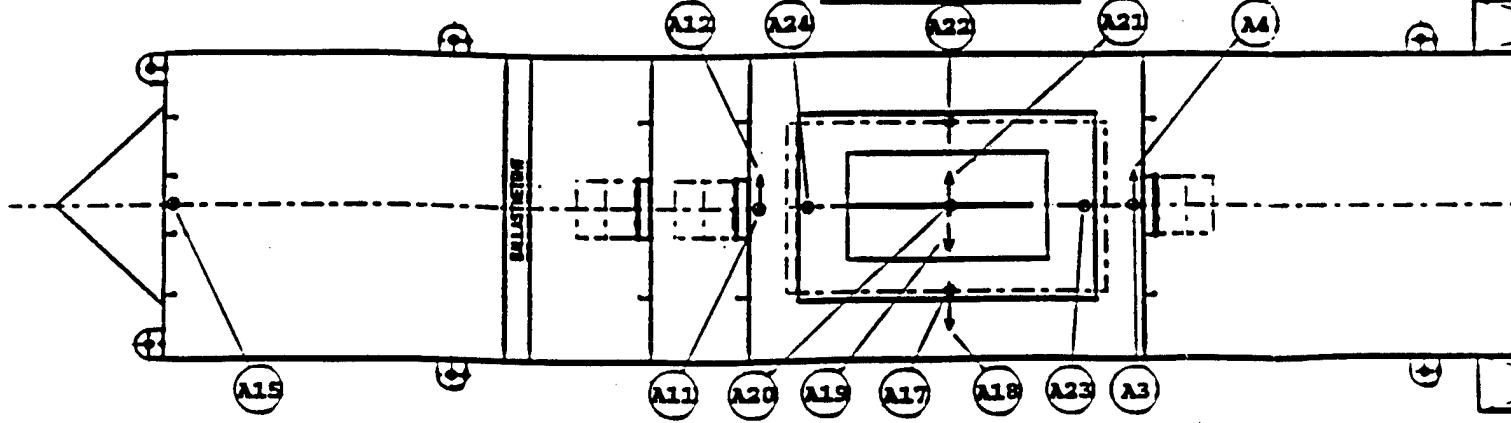
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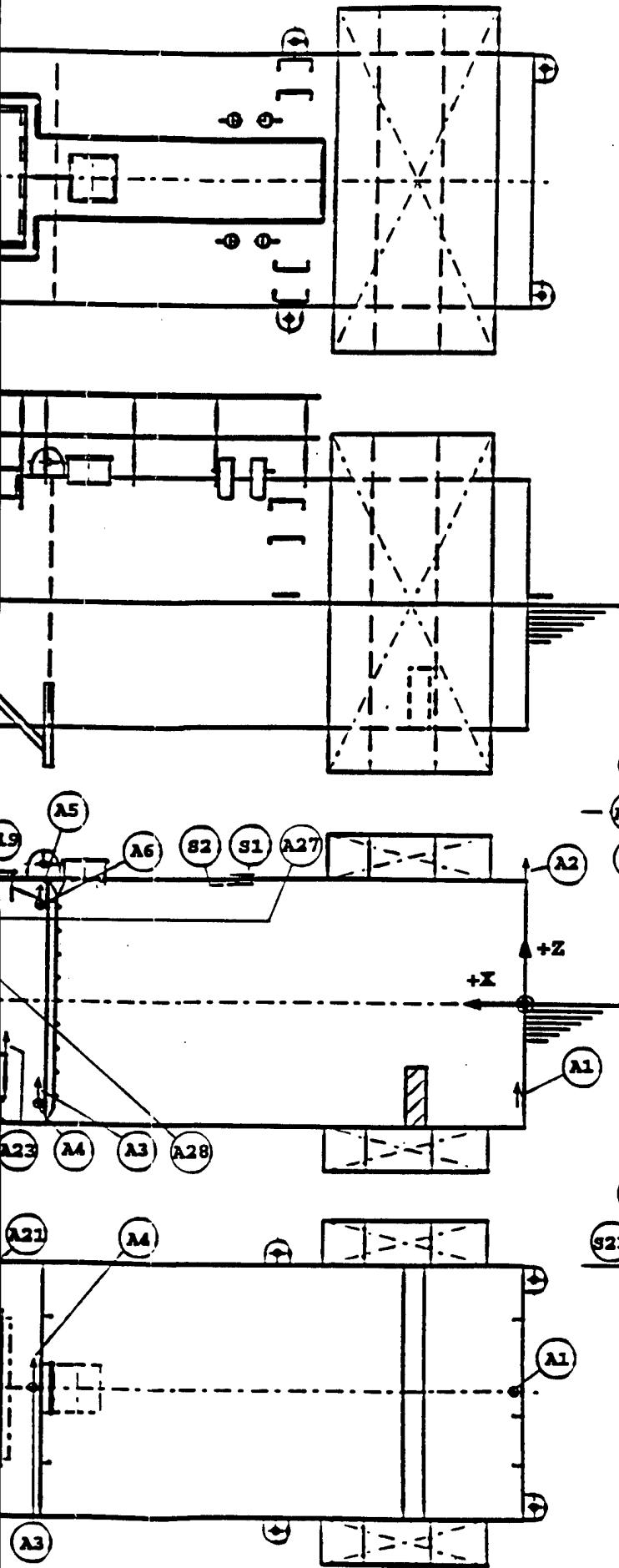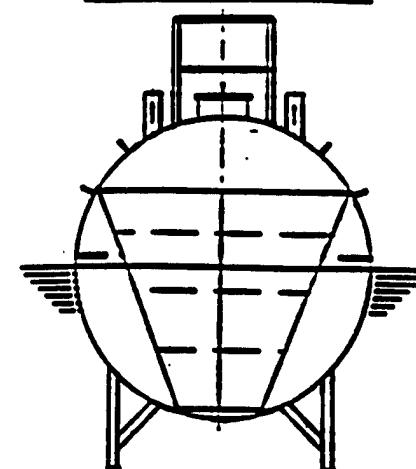
PRINCIPAL PARTICULARS

LENGTH TUBE	16.00 m
LENGTH O.A.	17.50 m
DIAMETER TUBE	3.10 m
DEPTH	1.55 m
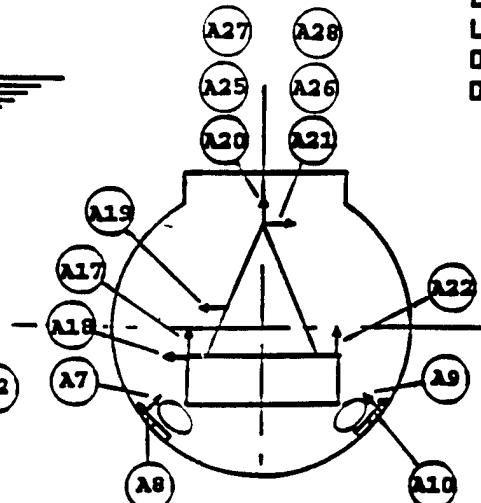
SECTION A-A

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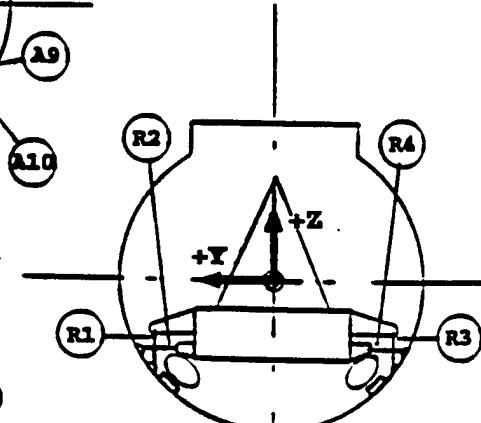
SECTION A-A

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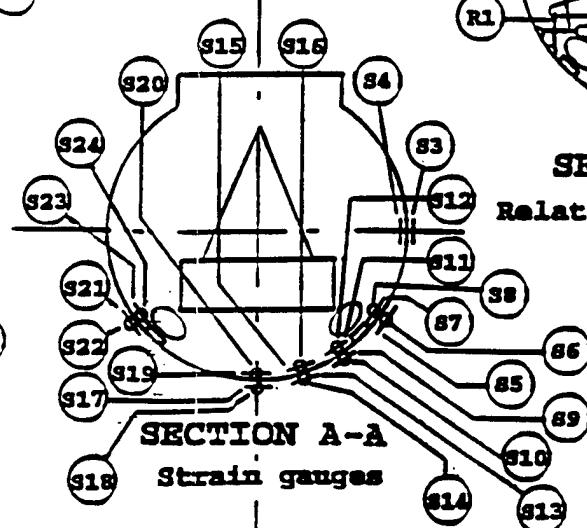
SECTION A-A

Strain gauges

Fig. 1

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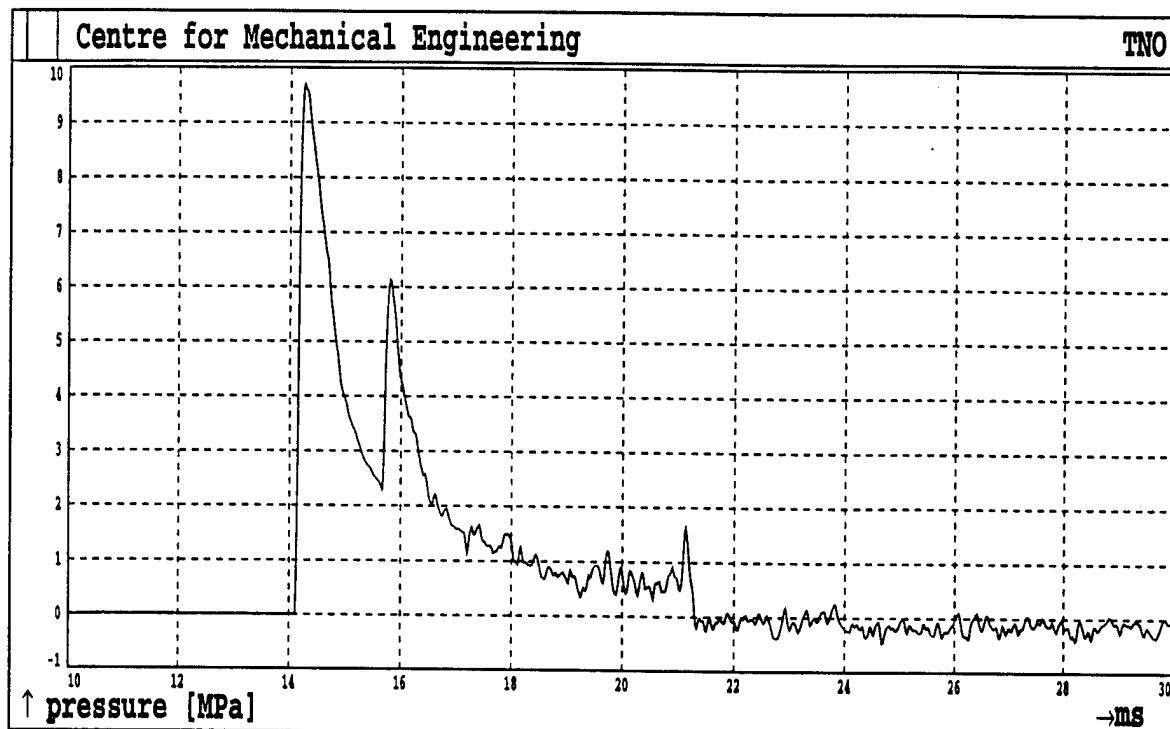
Fig.2. Shot 4   Sensor P1

Fig.3. Shot 4   Sensor P2

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↑ pressure [MPa]   → s

Fig.4. Shot 4   Sensor P1

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↑ pressure [MPa]   → s

Fig.5. Shot 4   Sensor P2

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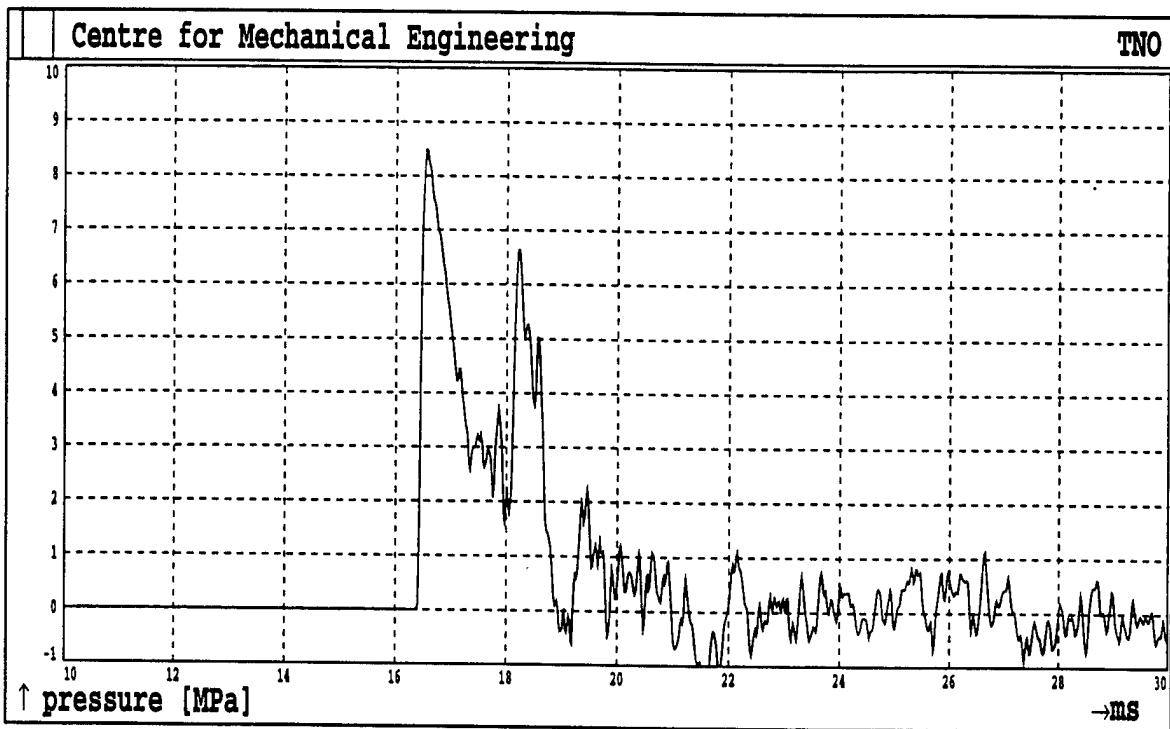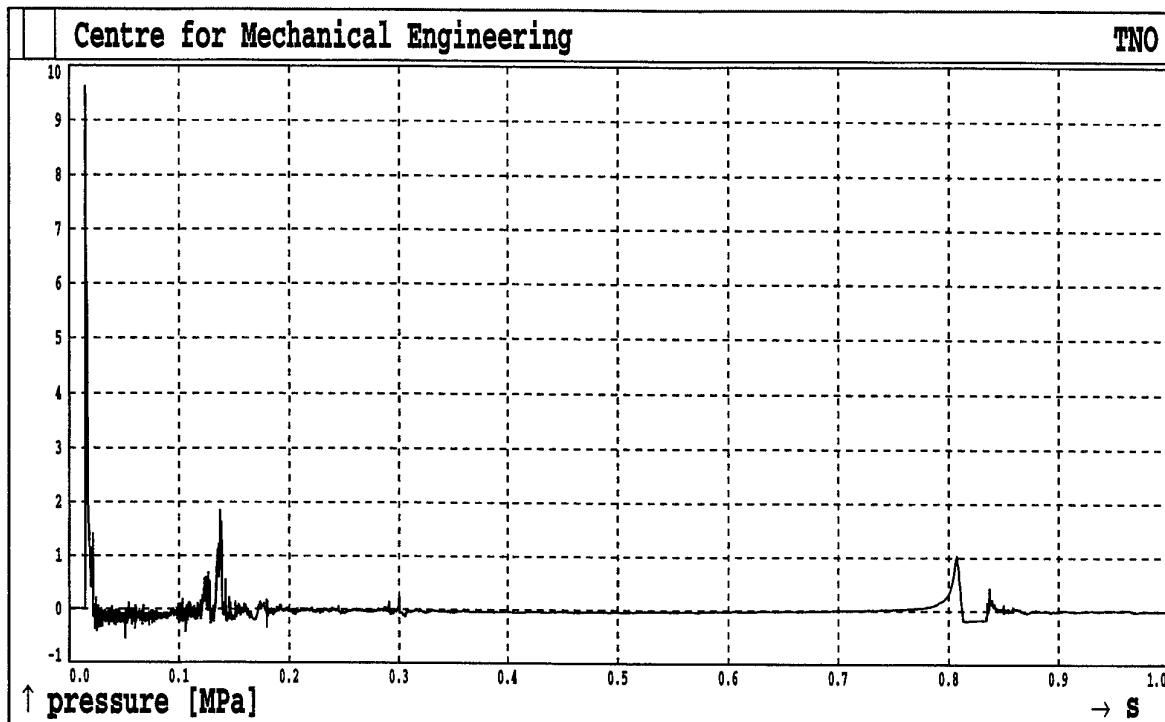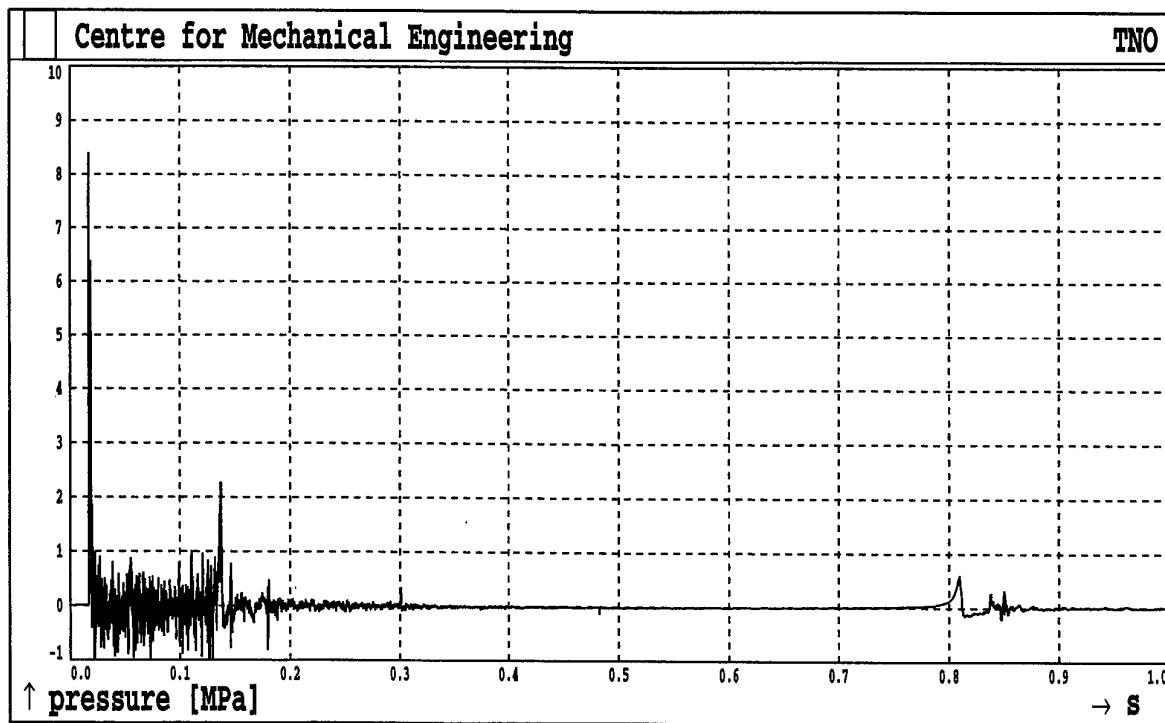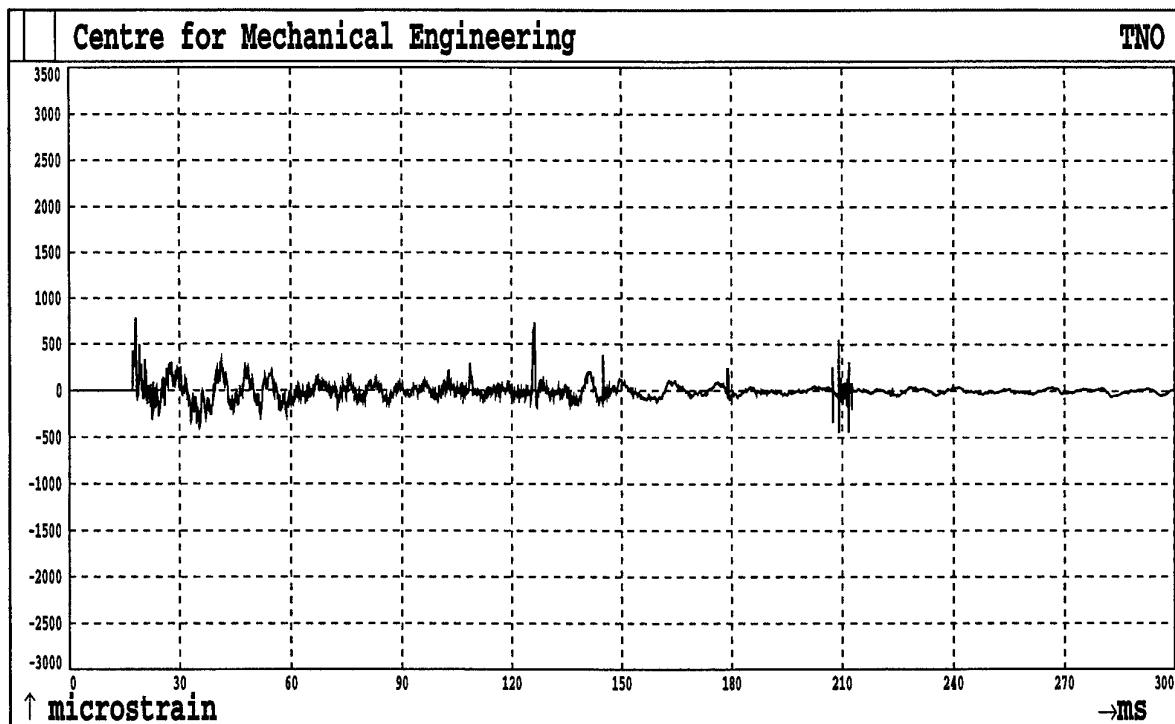
Fig.6. Shot 4   Sensor S1

Fig.7. Shot 4   Sensor S2

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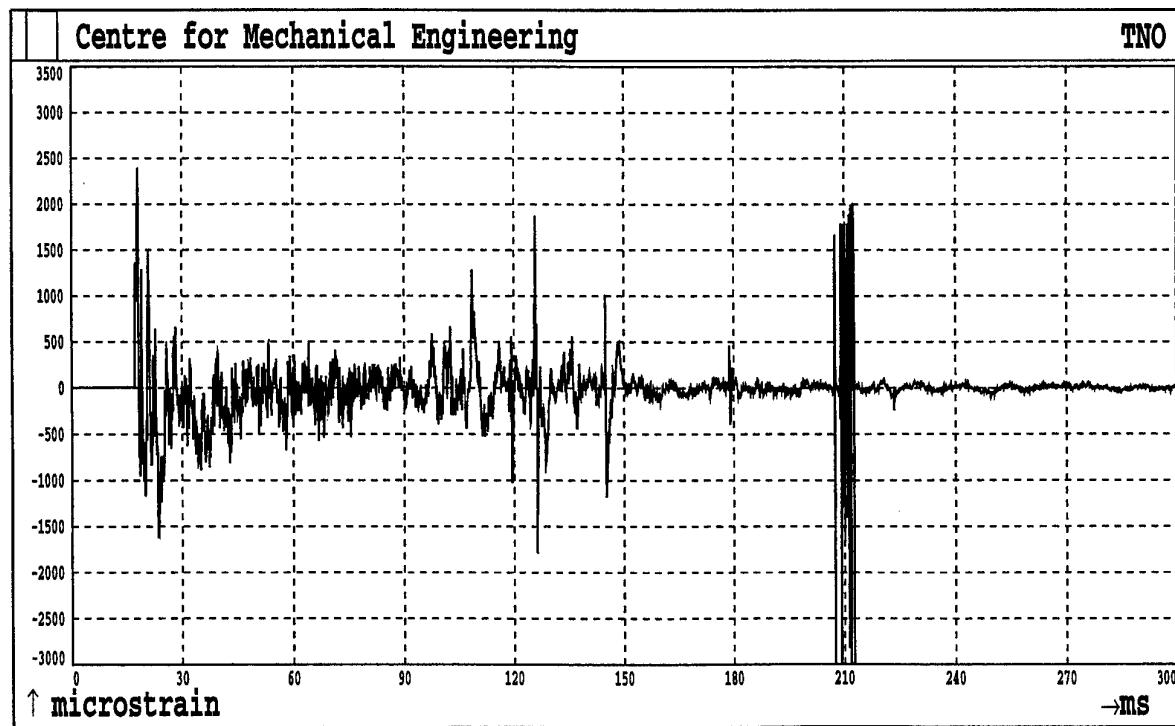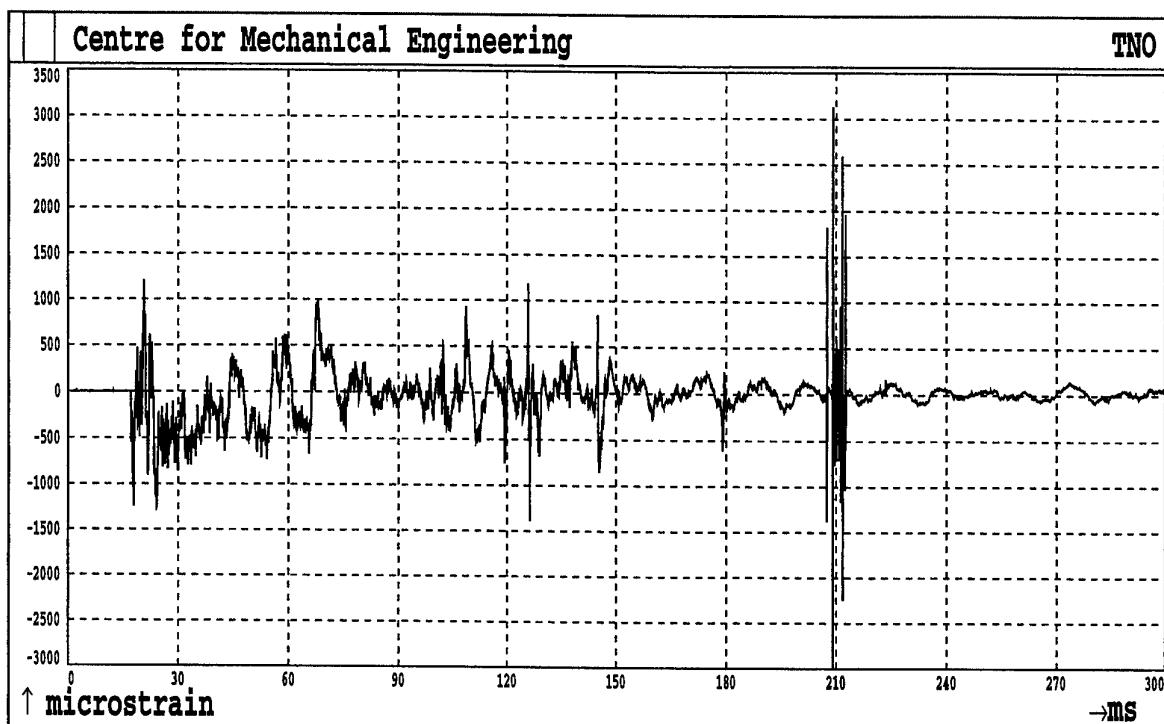
Fig.8. Shot 4   Sensor S3

Fig.9. Shot 4   Sensor S4

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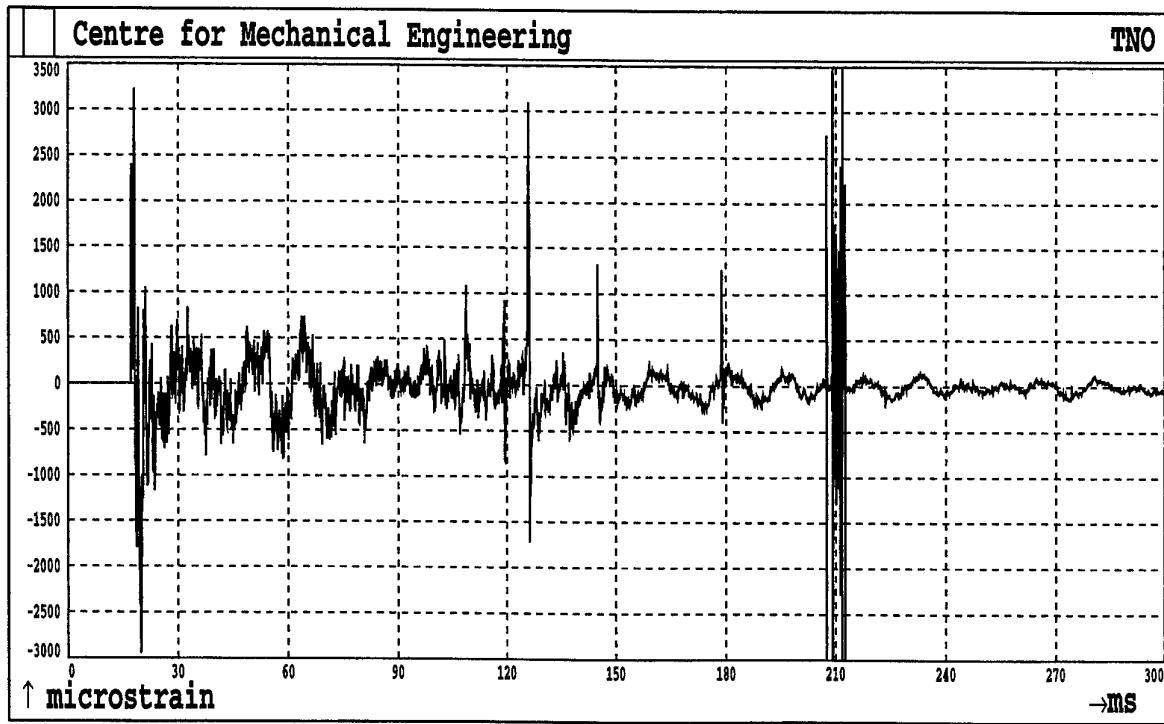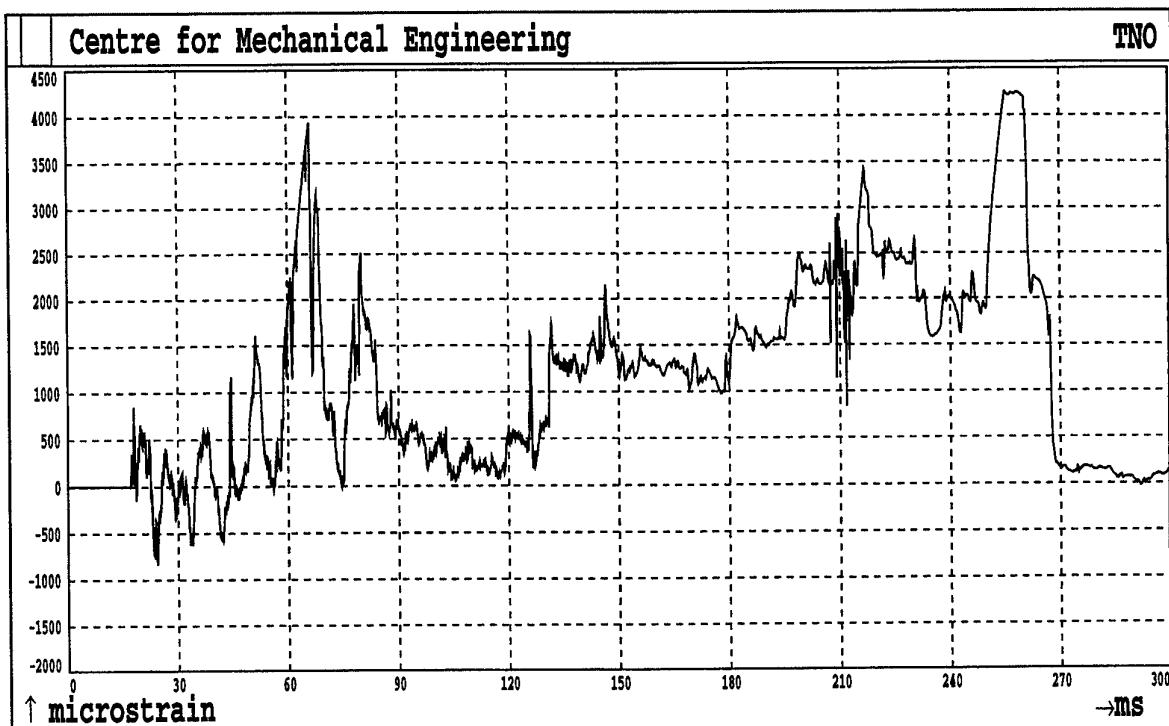
Fig.10. Shot 4   Sensor S5

Fig.11. Shot 4   Sensor S6
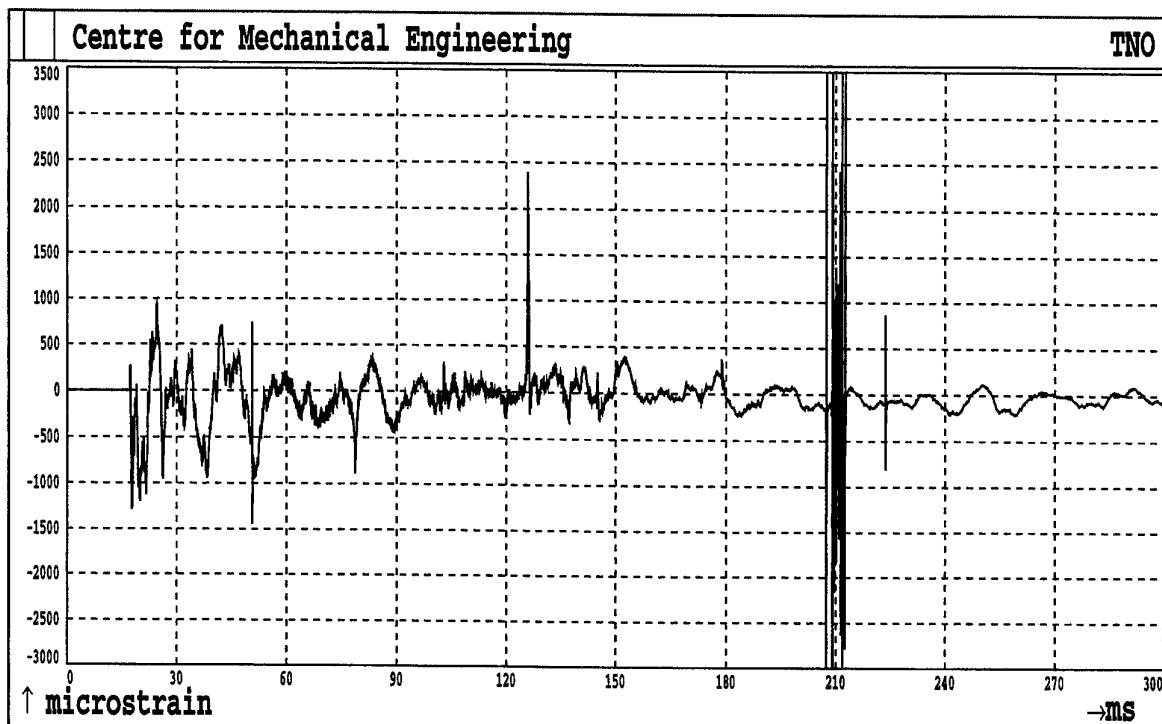
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Fig.12. Shot 4 Sensor S7

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Fig.13. Shot 4 Sensor S8

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Centre for Mechanical Engineering   **TNO**

↑ microstrain   →ms

Fig.14. Shot 4   Sensor S11

Centre for Mechanical Engineering   **TNO**

↑ microstrain   →ms

Fig.15. Shot 4   Sensor S12

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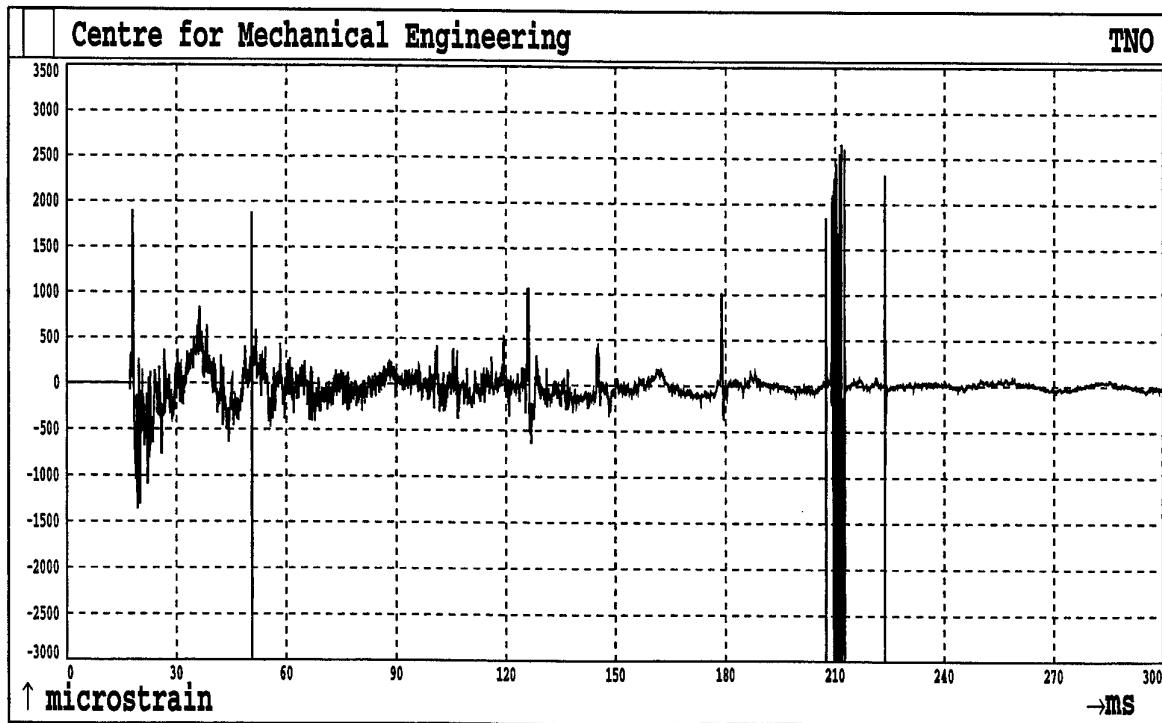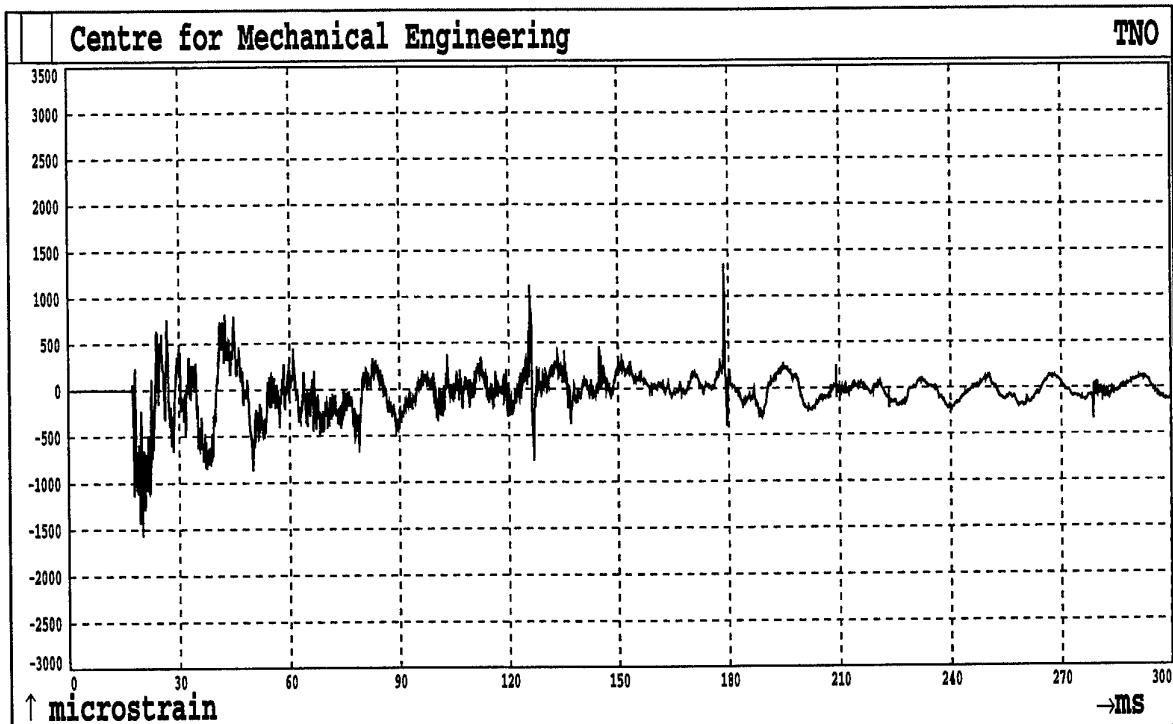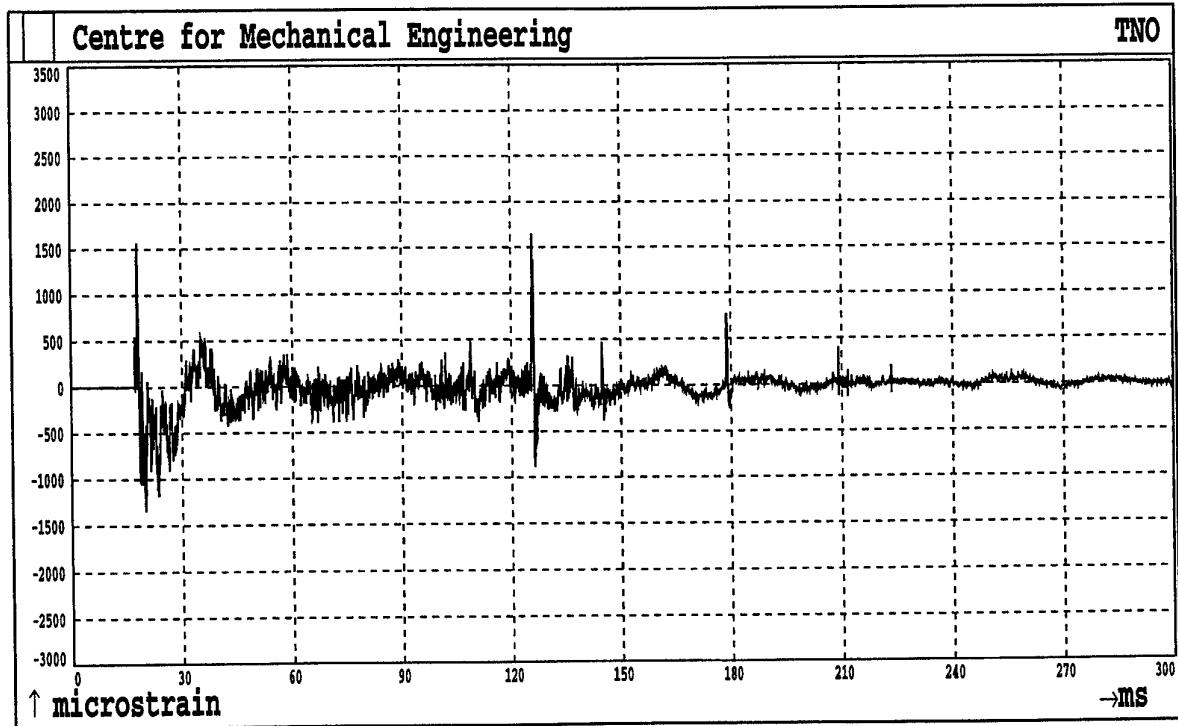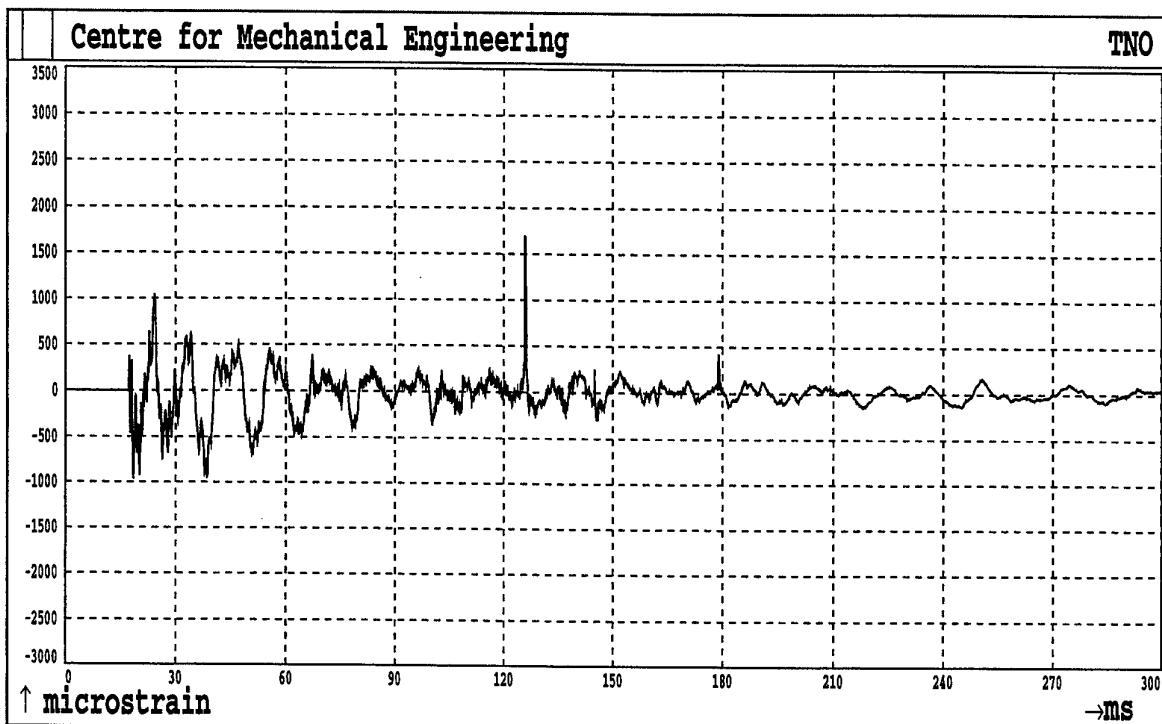
Fig.16. Shot 4   Sensor S13

Fig.17. Shot 4   Sensor S14

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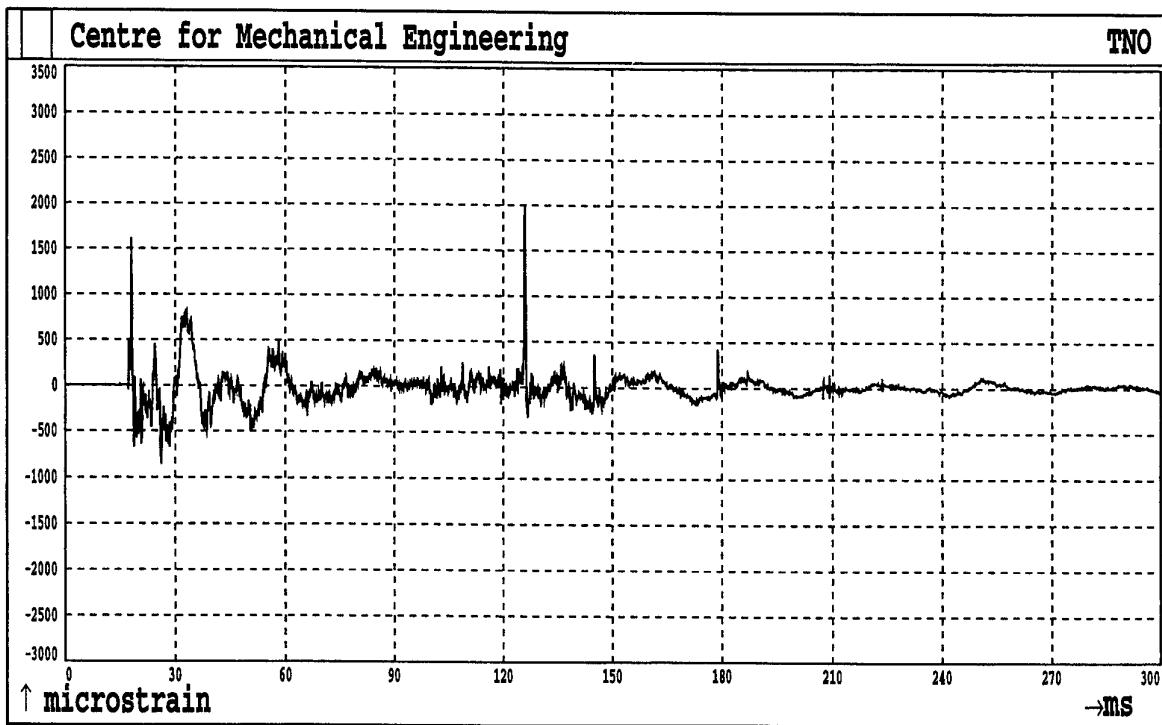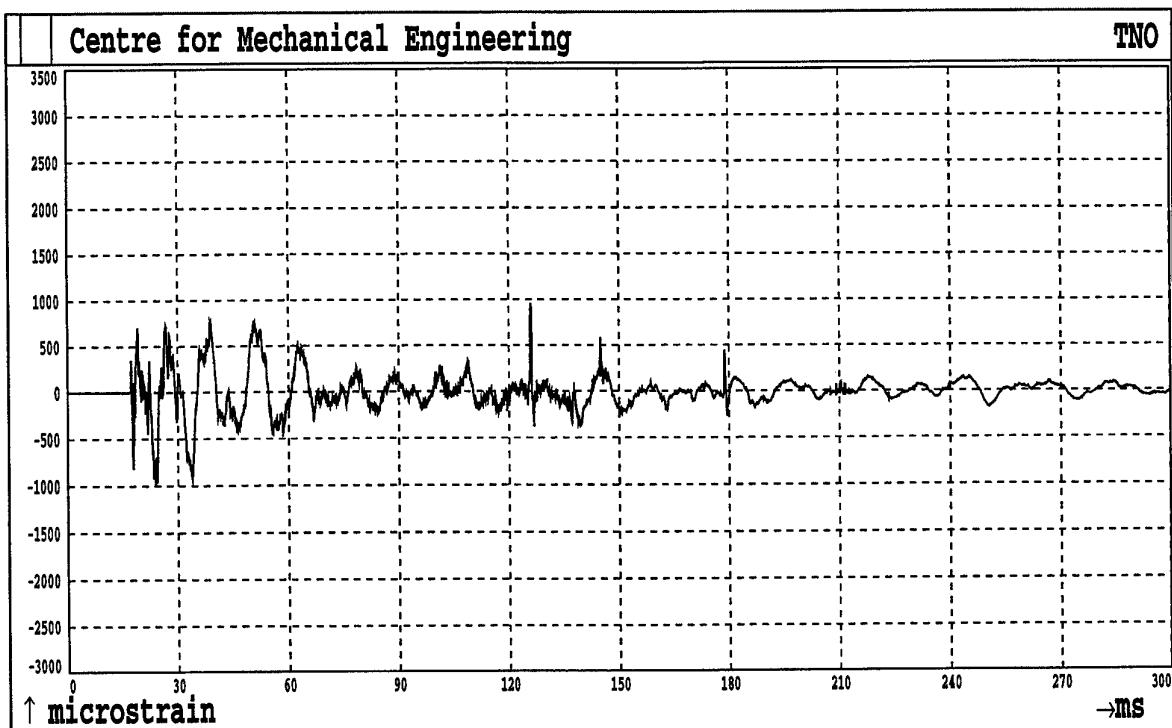
Fig.18. Shot 4   Sensor S15

Fig.19. Shot 4   Sensor S16

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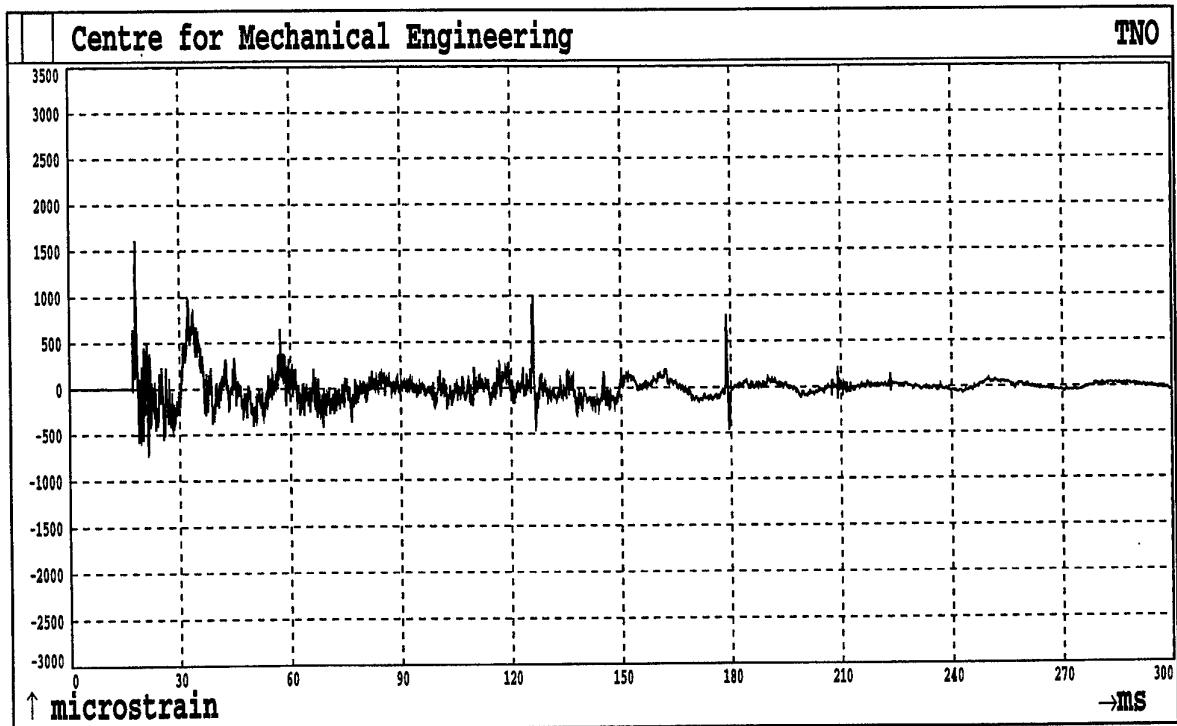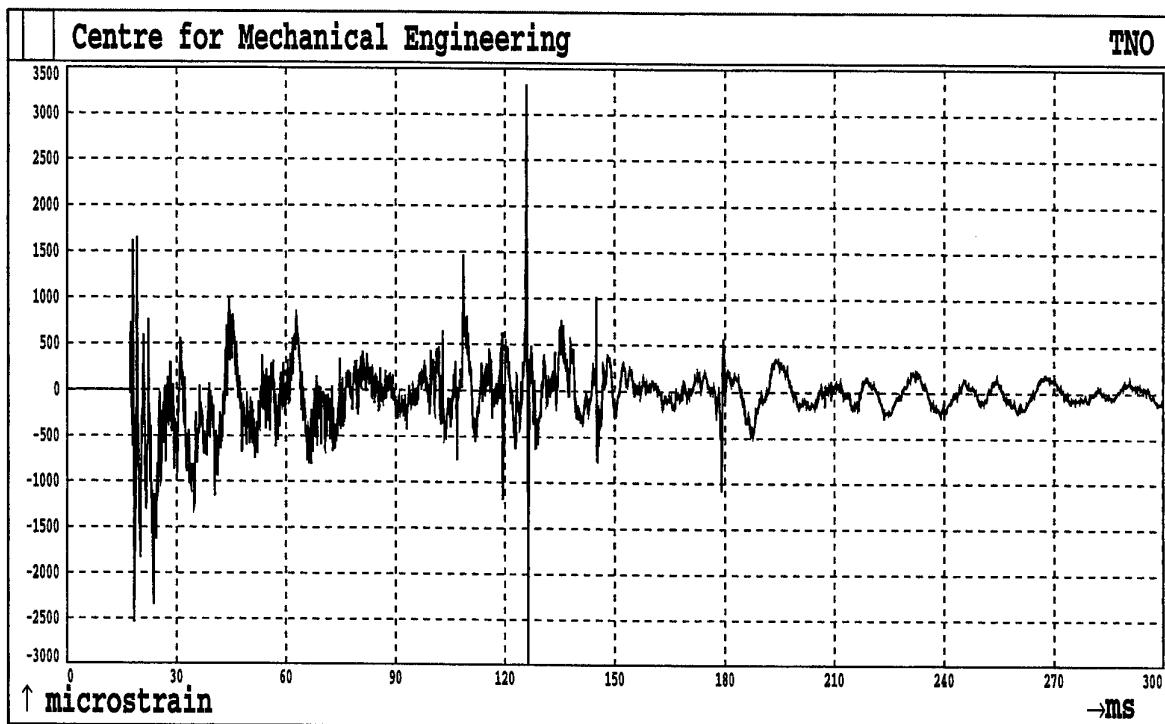
Fig.20. Shot 4   Sensor S17
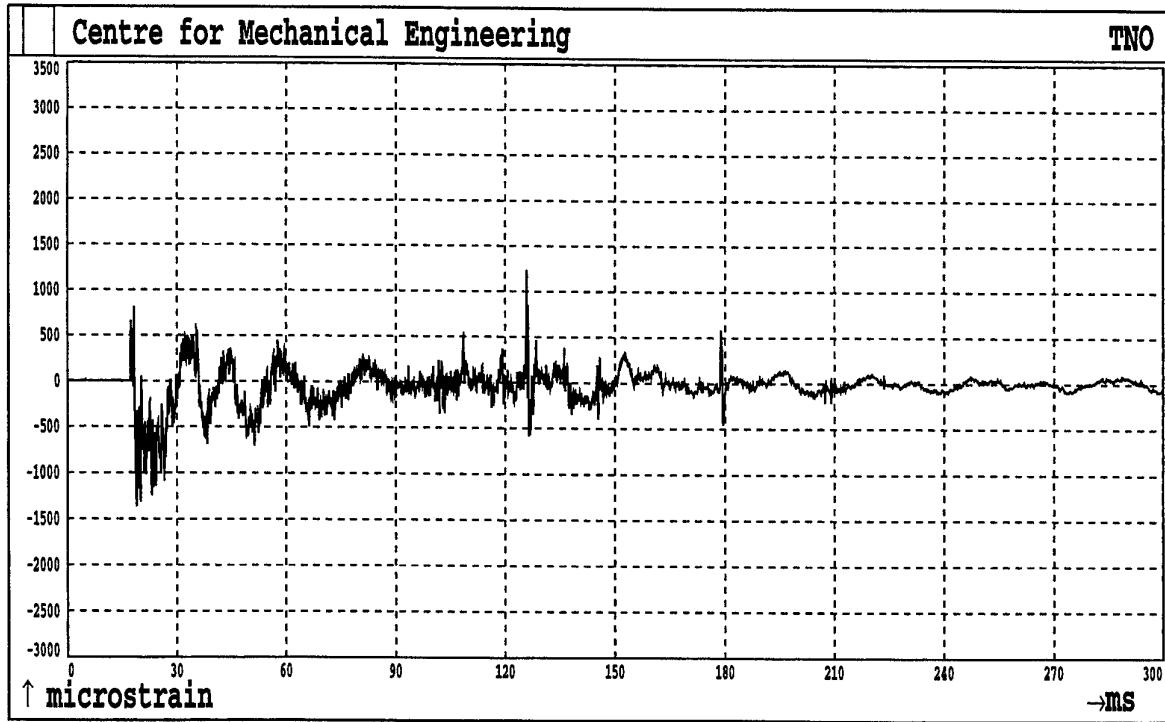
Fig.21. Shot 4   Sensor S18
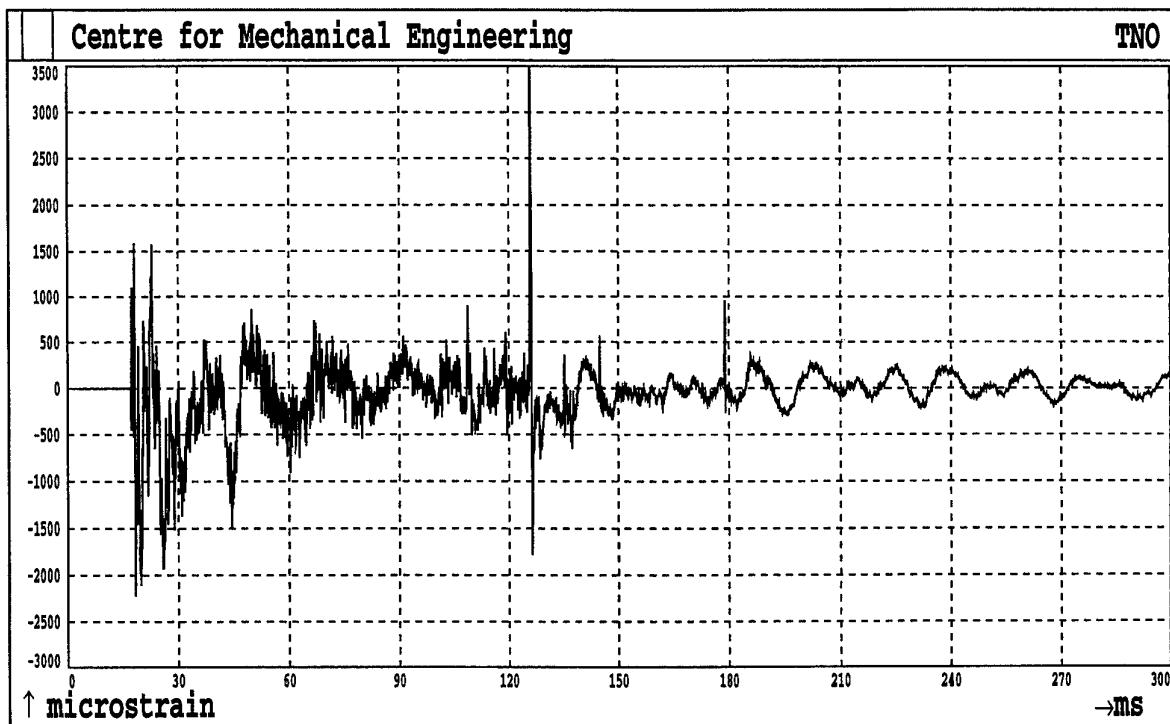
Fig.22. Shot 4   Sensor S19

Fig.23. Shot 4   Sensor S20

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A.13
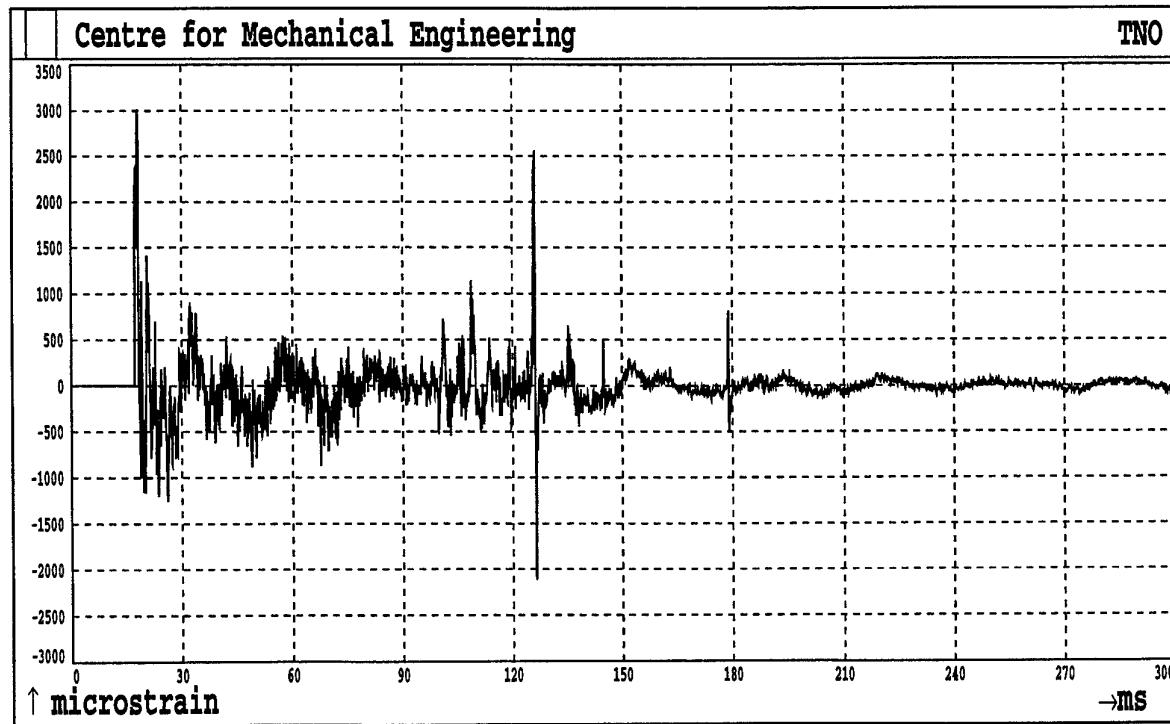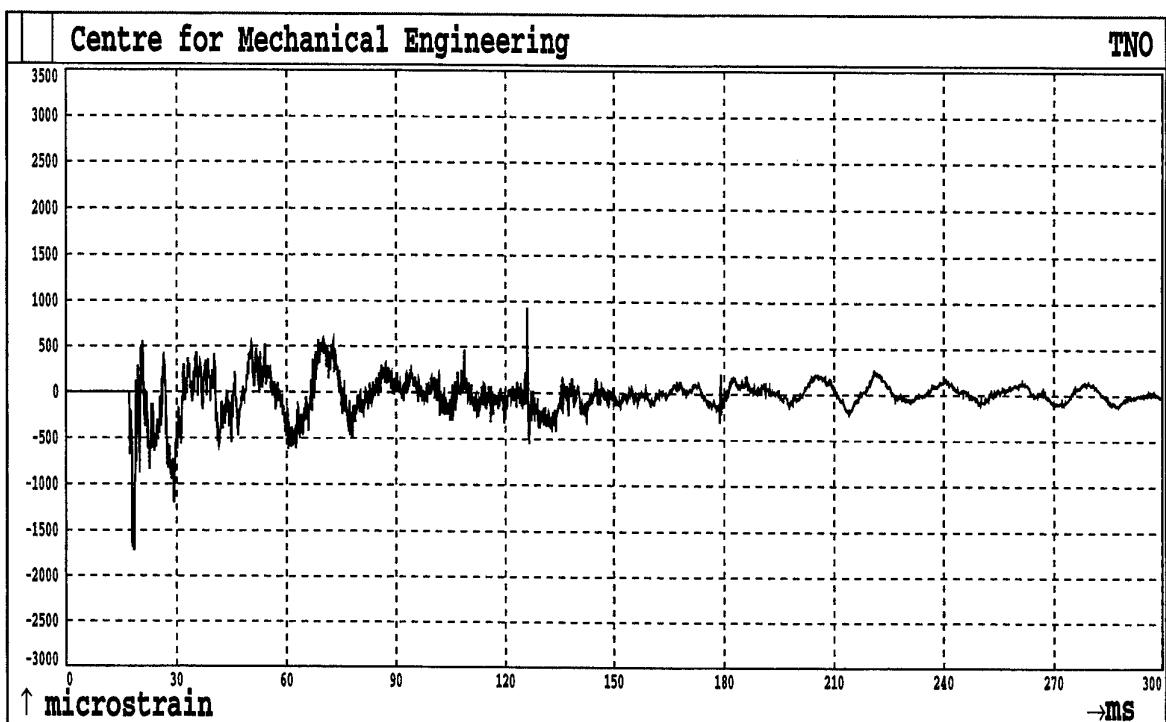
Fig.24. Shot 4   Sensor S21

Fig.25. Shot 4   Sensor S22
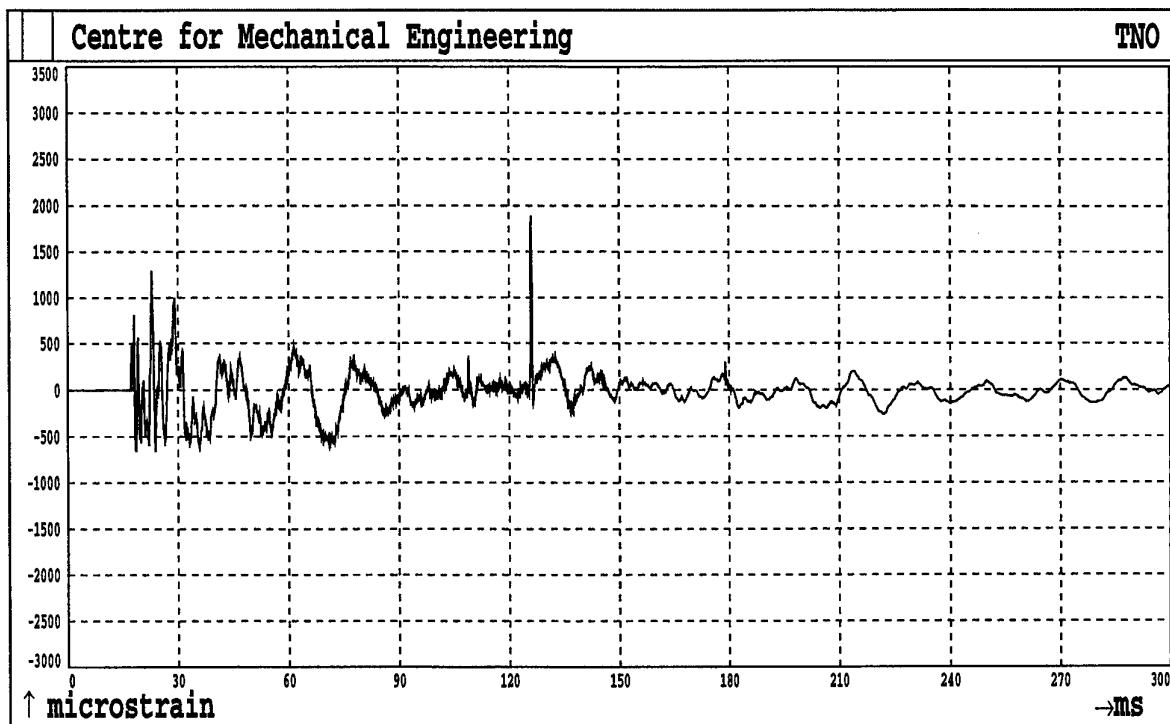
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↑ microstrain   →ms

Fig.26. Shot 4   Sensor S23

Centre for Mechanical Engineering   TNO

↑ microstrain   →ms

Fig.27. Shot 4   Sensor S24

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Centre for Mechanical Engineering TNO

↑ microstrain →ms

Fig.28. Shot 4   Sensor S25

Centre for Mechanical Engineering TNO

↑ microstrain →ms

Fig.29. Shot 4   Sensor S26

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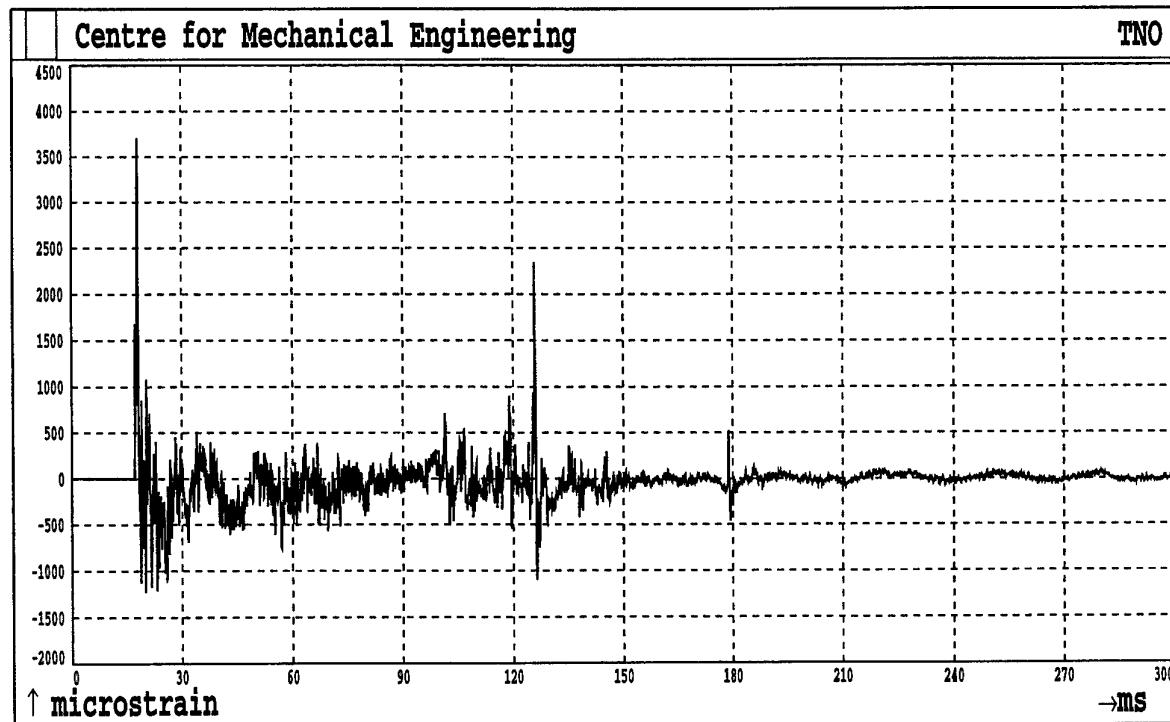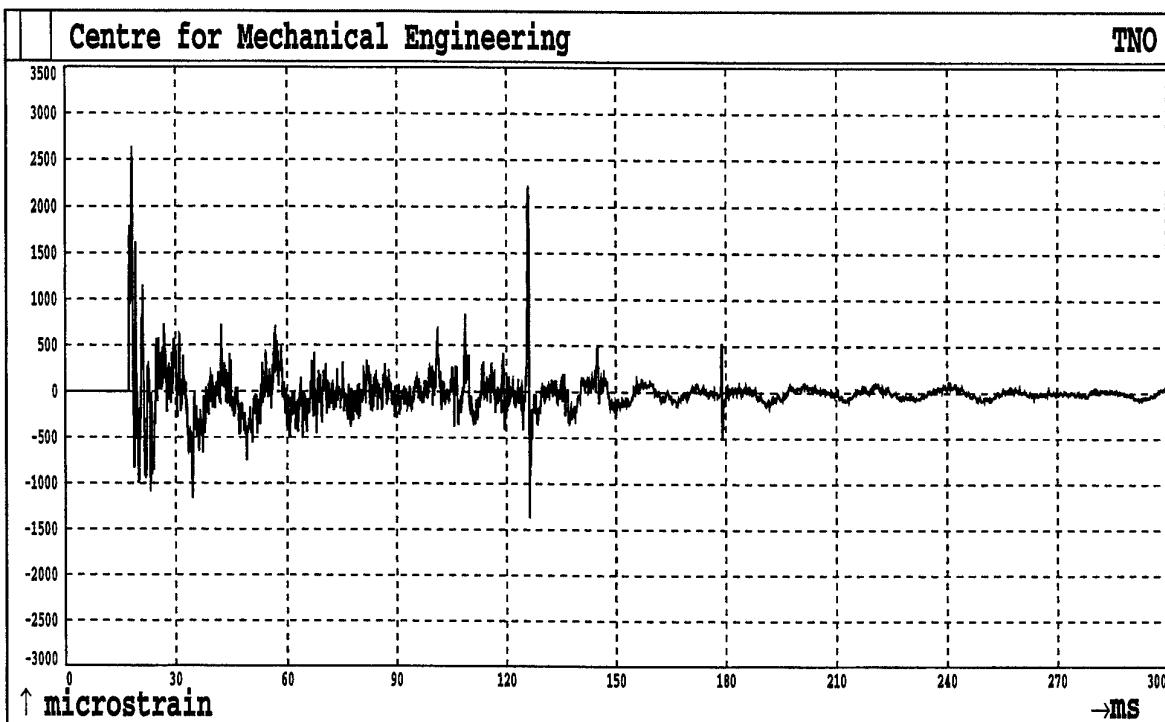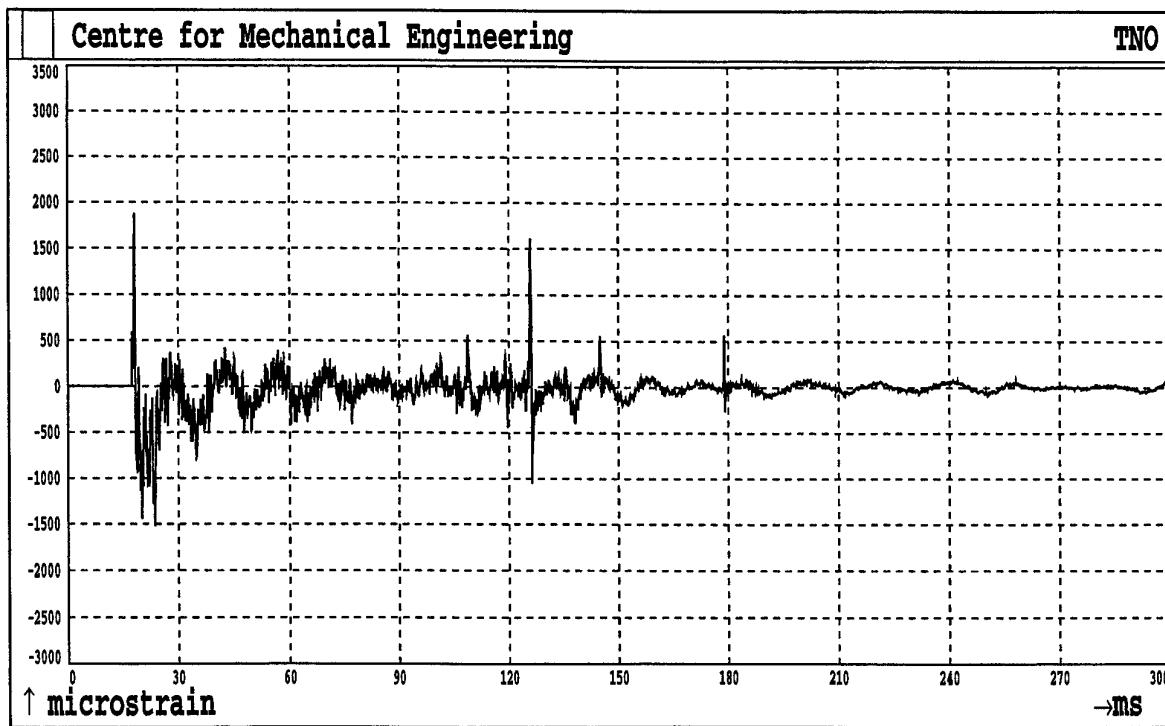
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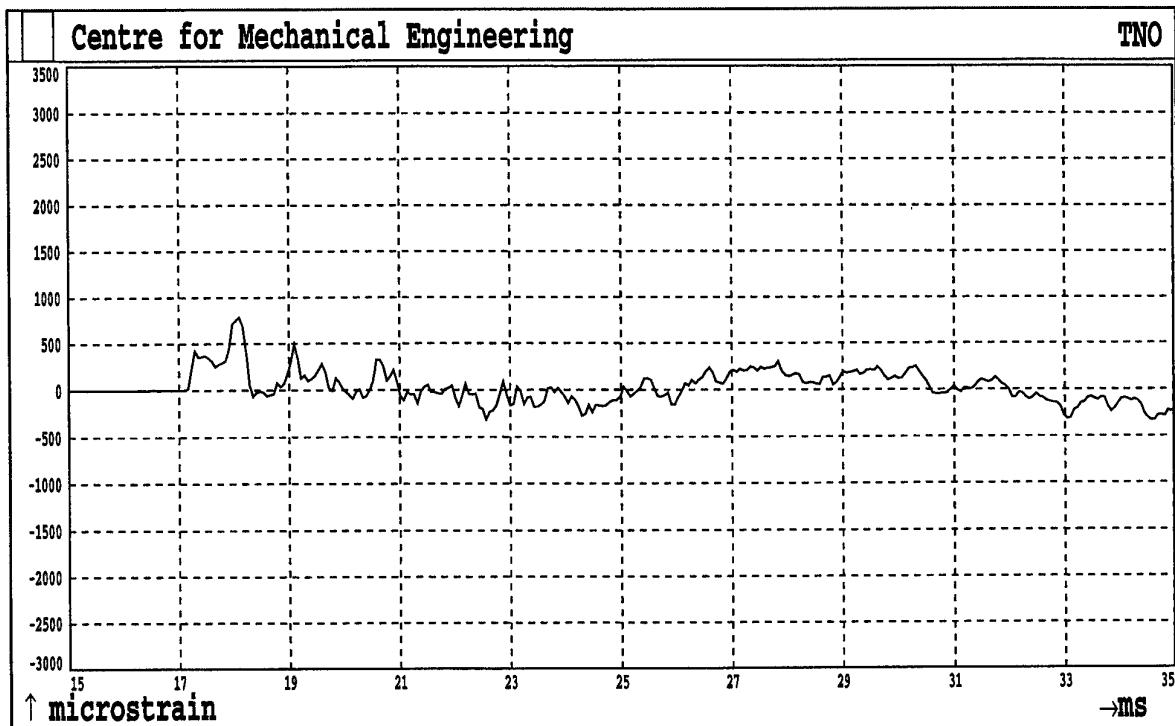
Fig.30. Shot 4   Sensor S1

Fig.31. Shot 4   Sensor S2

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A.17
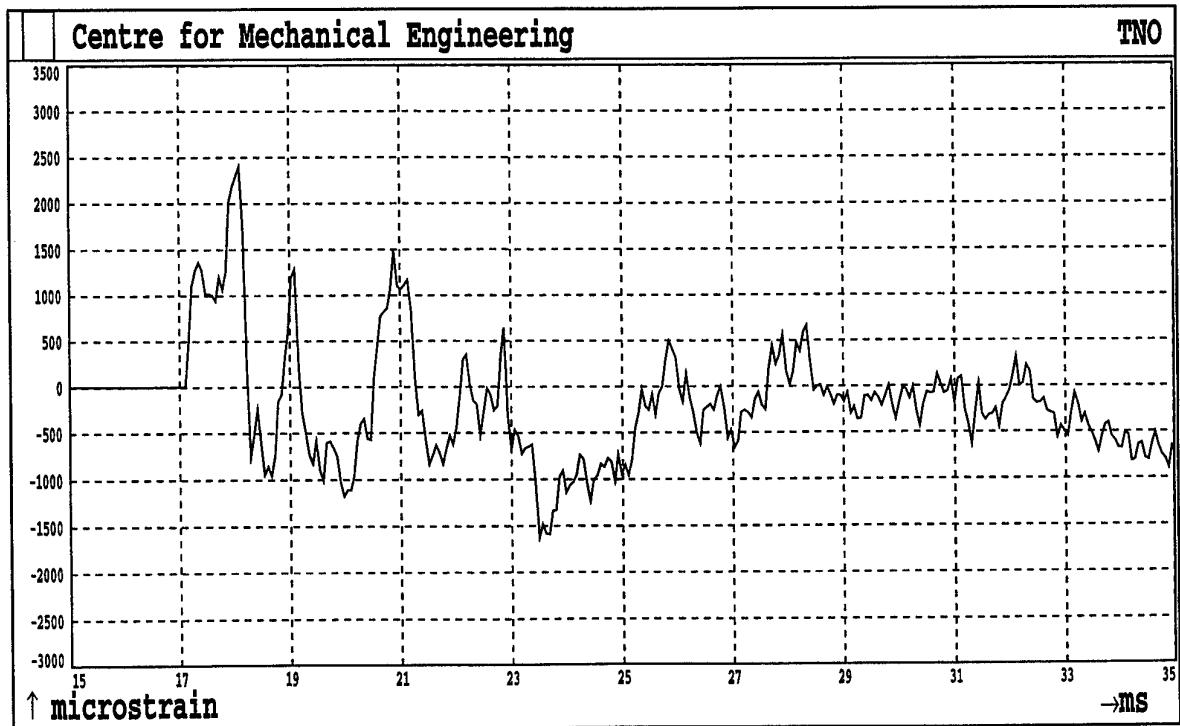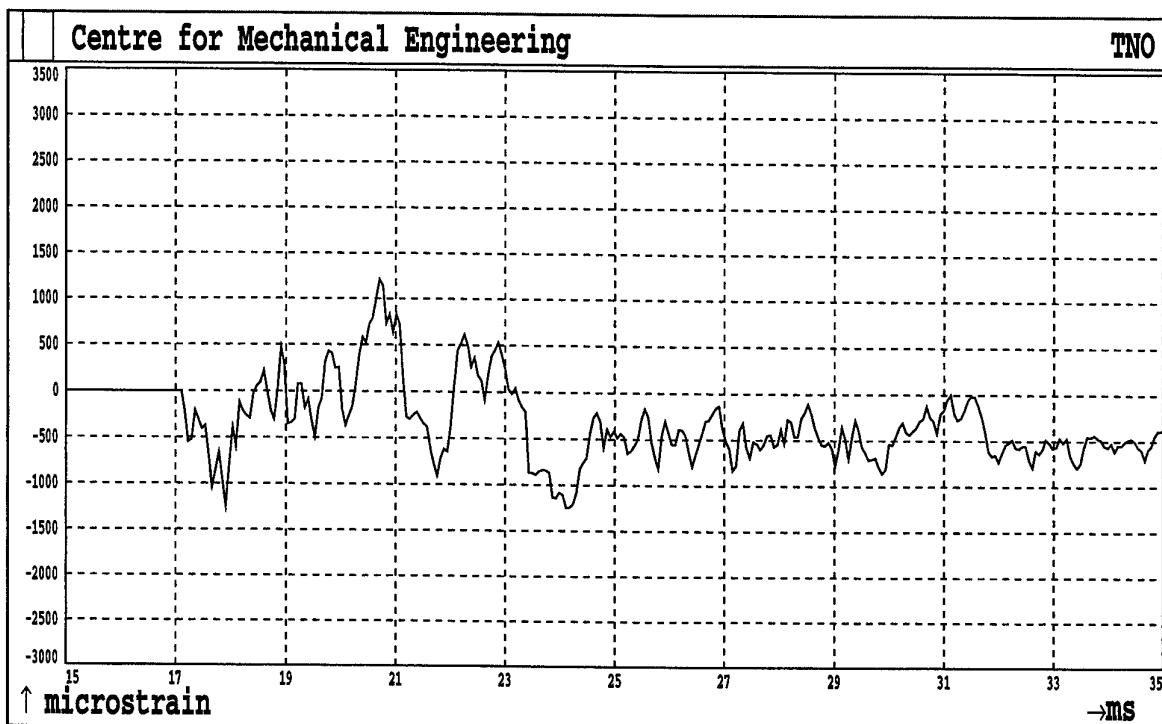
Fig.32. Shot 4   Sensor S3

Fig.33. Shot 4   Sensor S4

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A.18
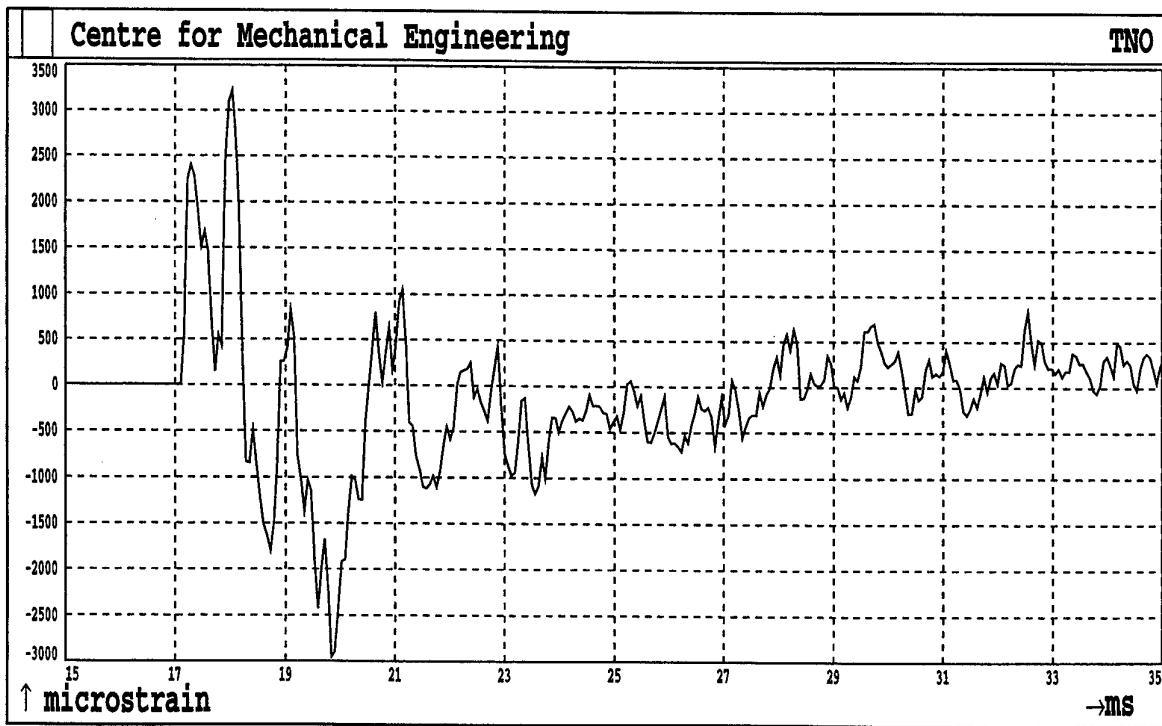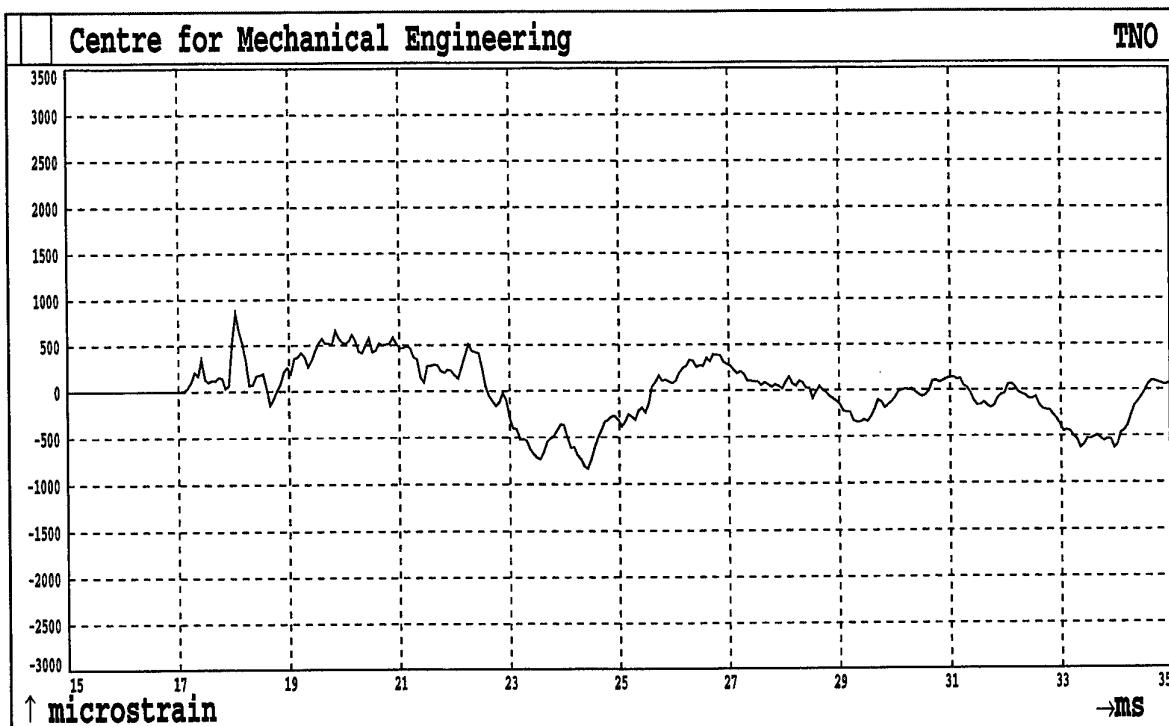
Fig.34. Shot 4   Sensor S5

Fig.35. Shot 4   Sensor S6

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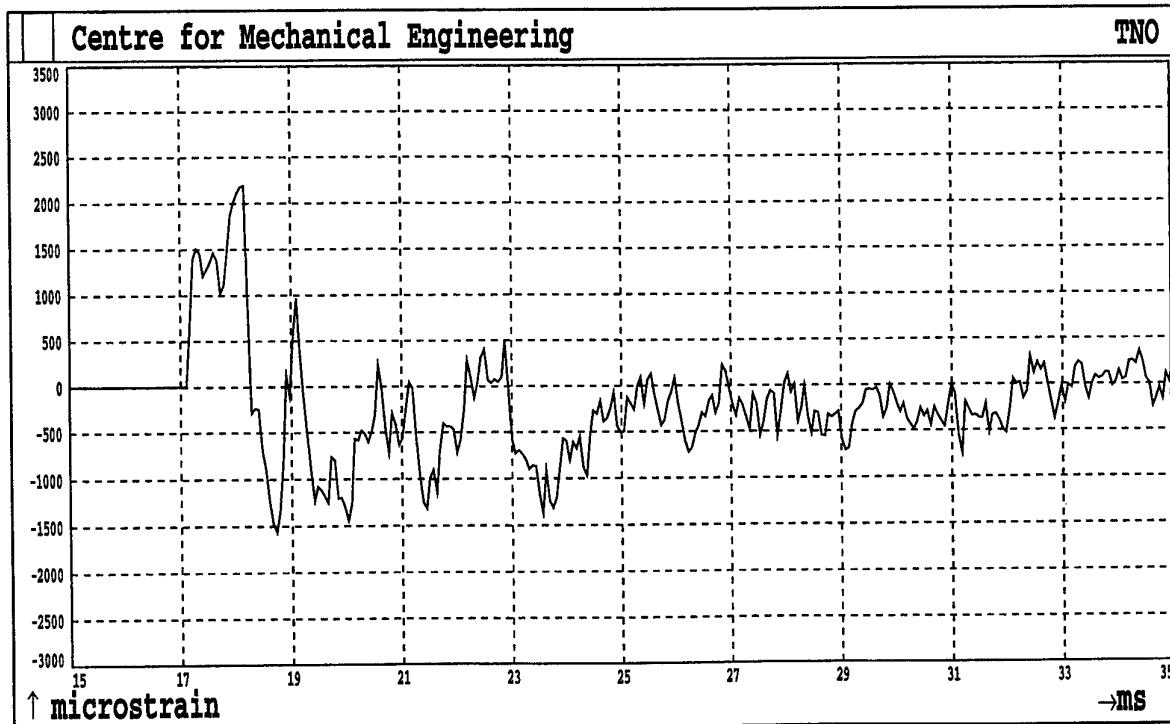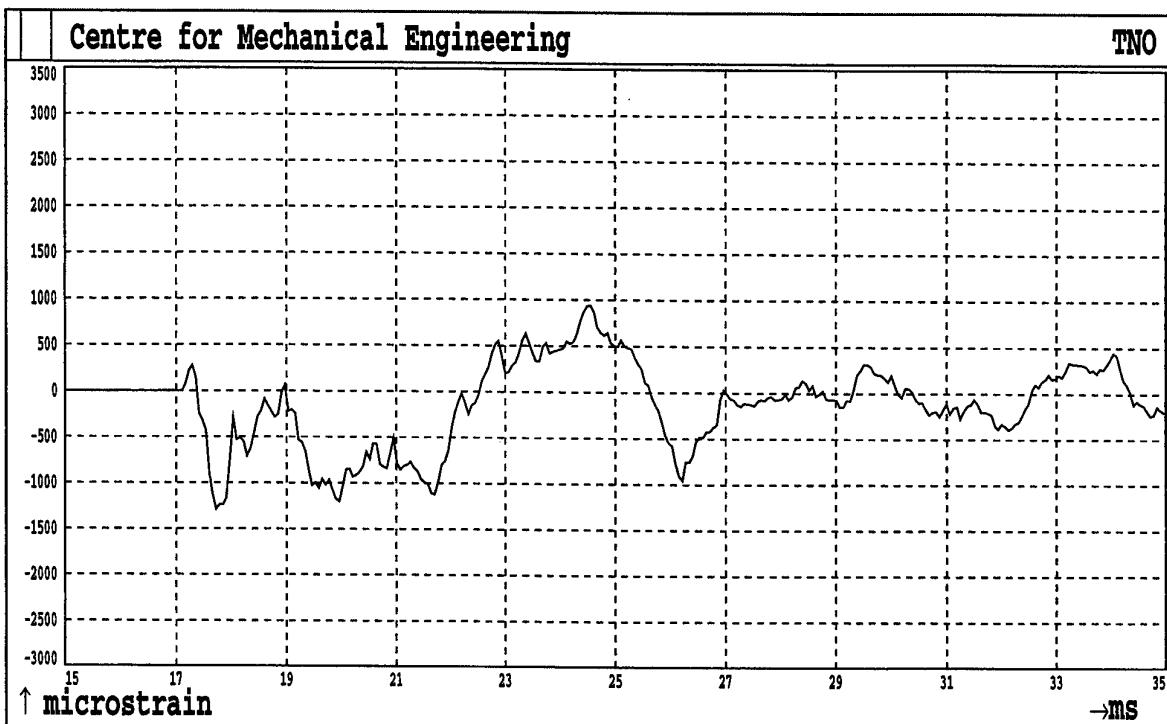
Fig.36. Shot 4   Sensor S7

Fig.37. Shot 4   Sensor S8

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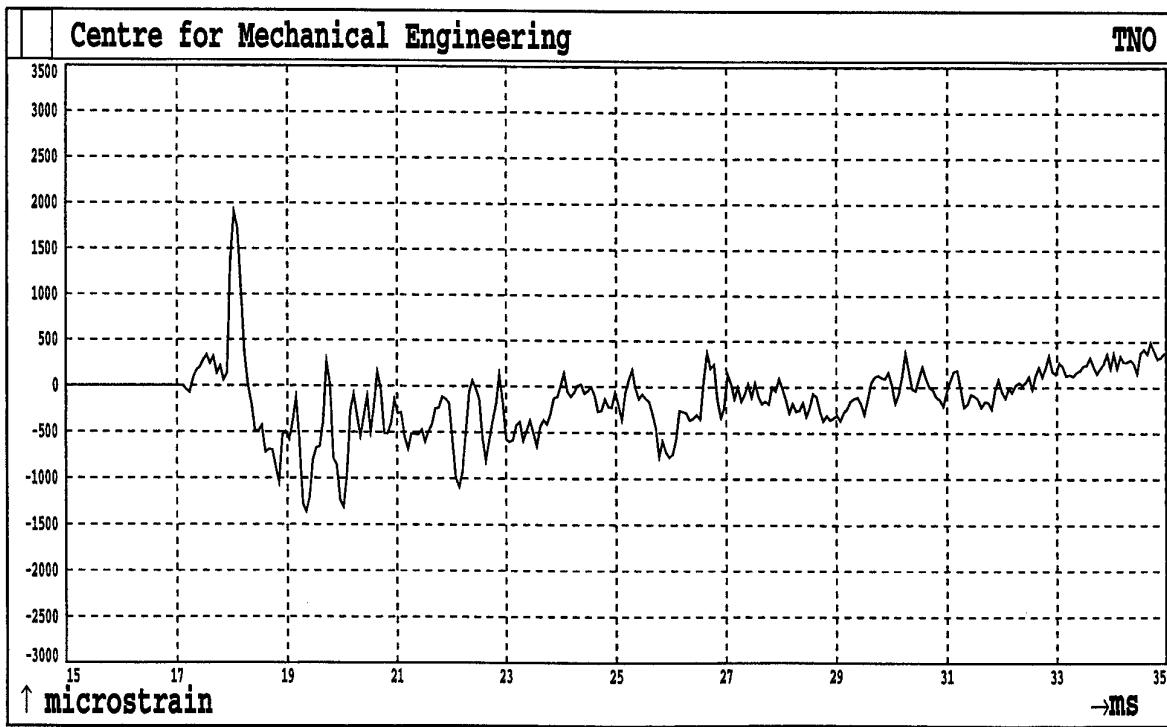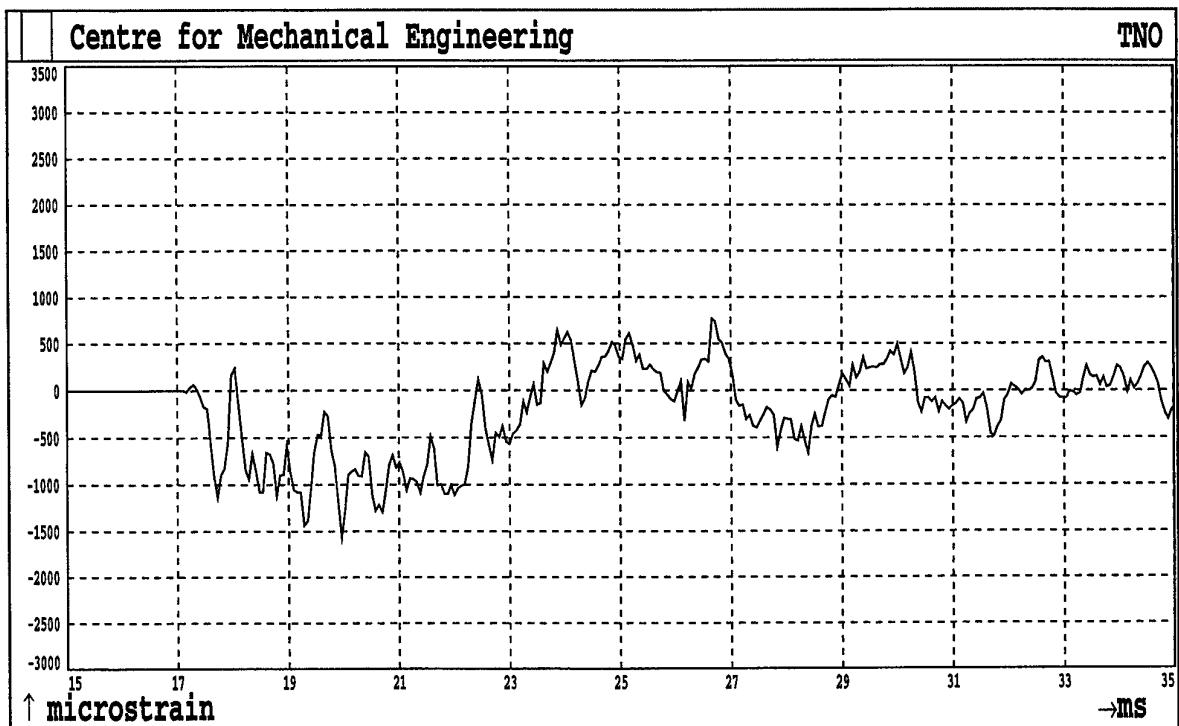
Fig.38. Shot 4   Sensor S11
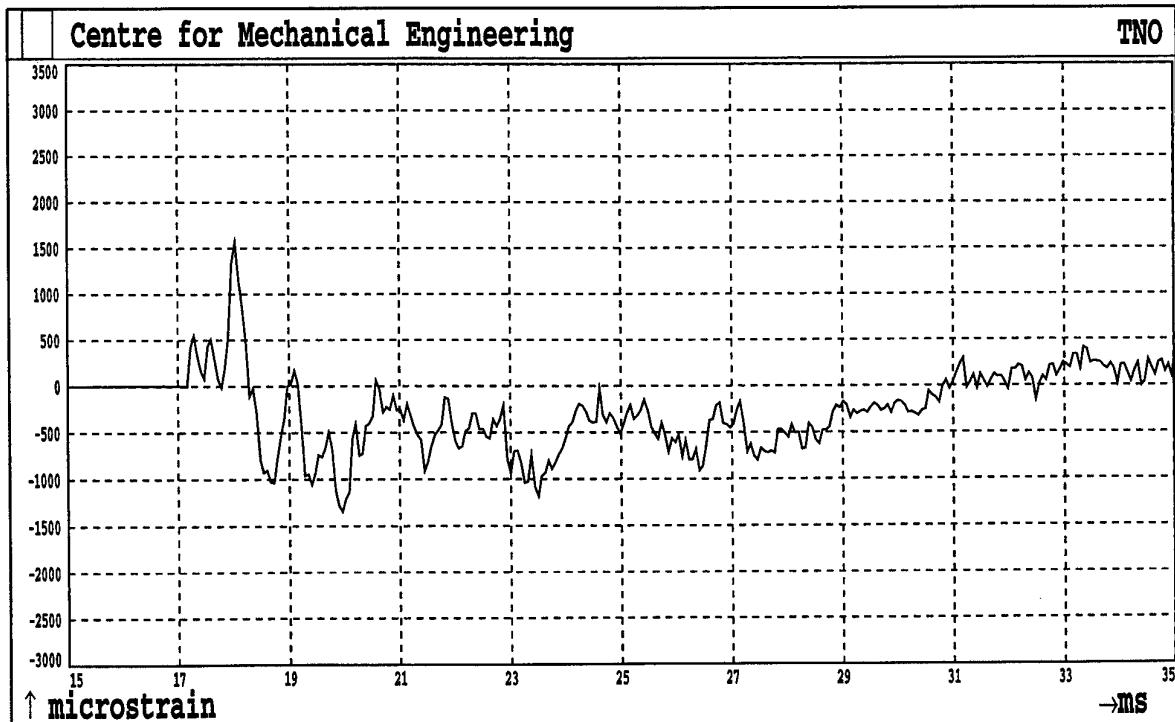
Fig.39. Shot 4   Sensor S12
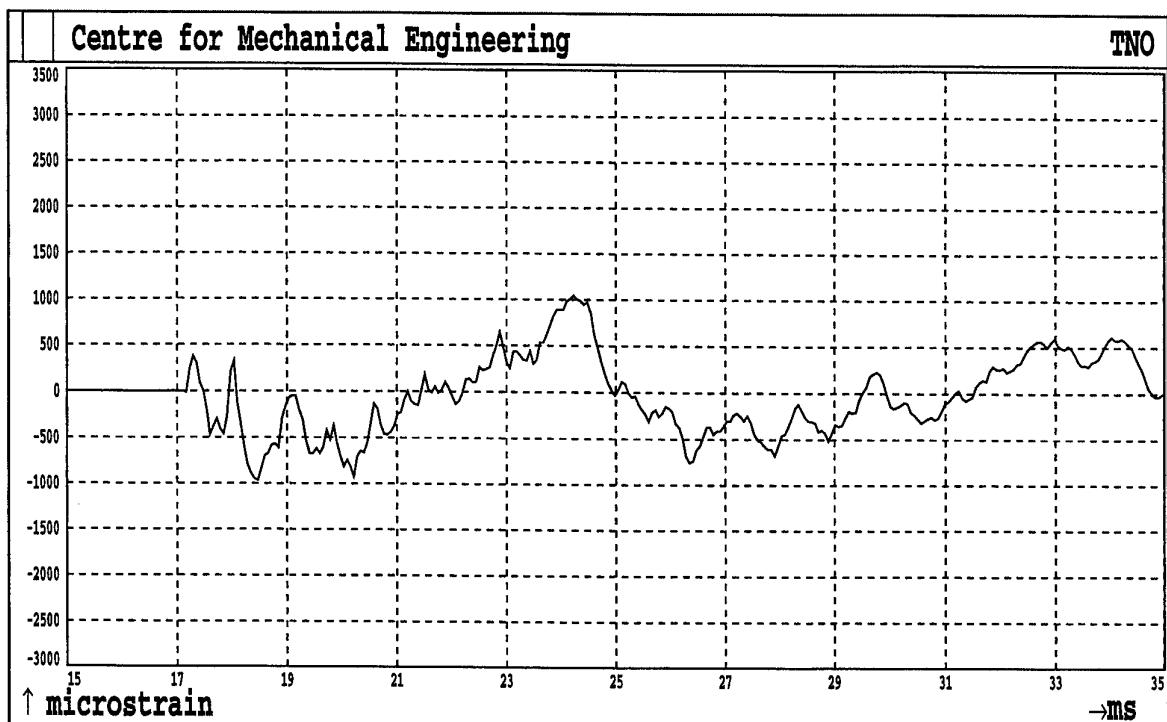
Fig.40. Shot 4   Sensor S13

Fig.41. Shot 4   Sensor S14

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Fig.42. Shot 4   Sensor S15

Fig.43. Shot 4   Sensor S16

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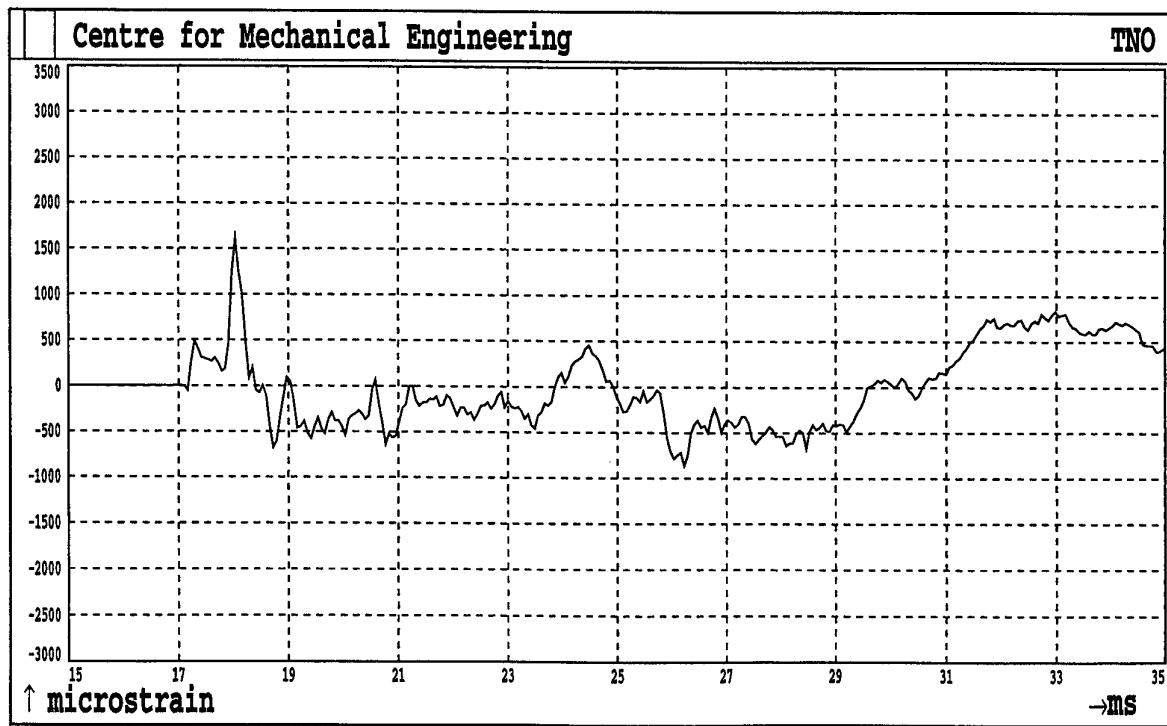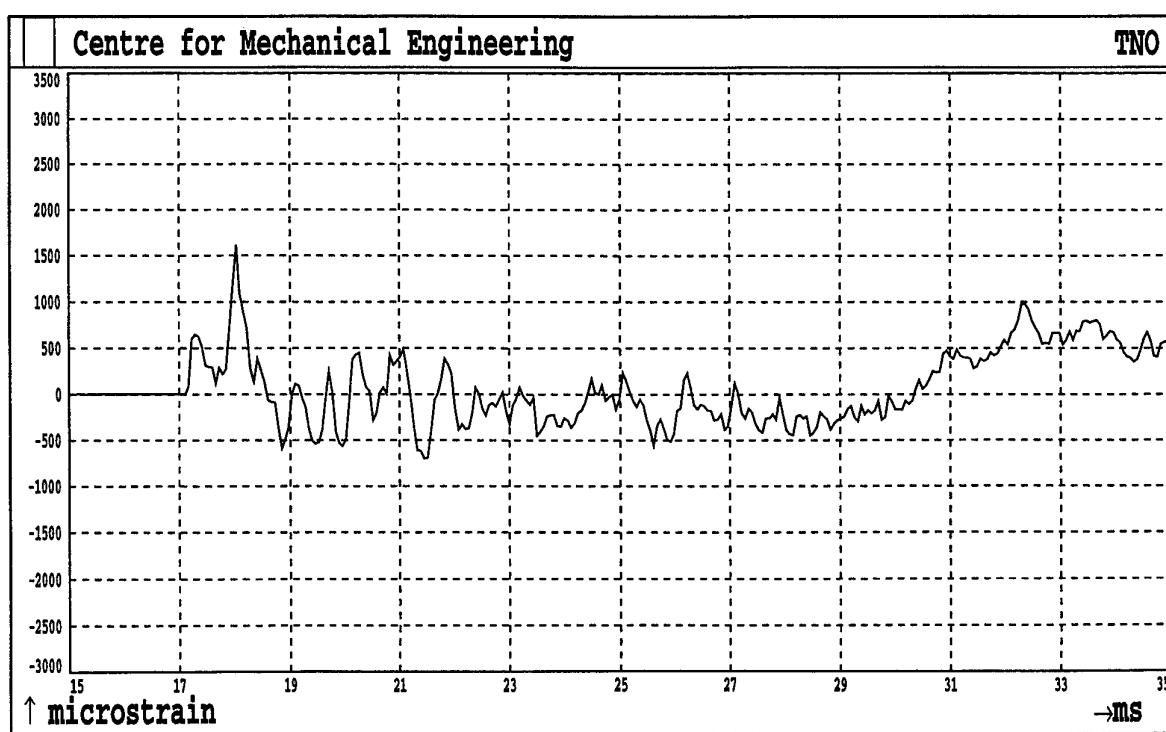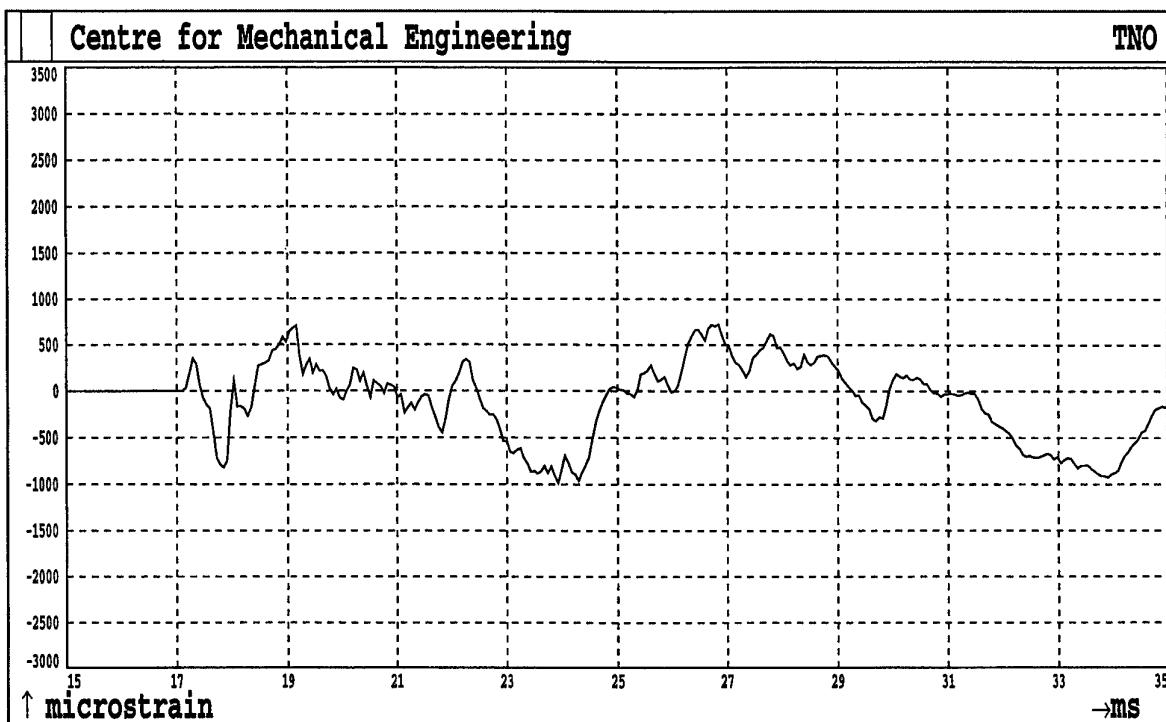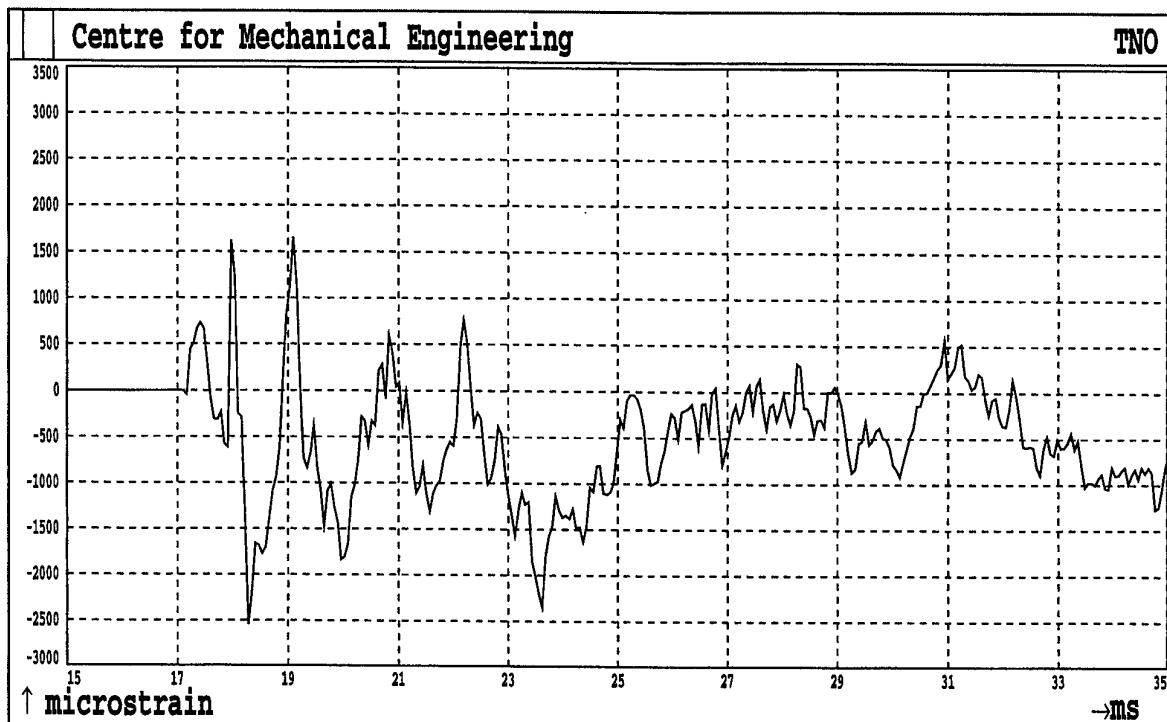
Fig.44. Shot 4   Sensor S17
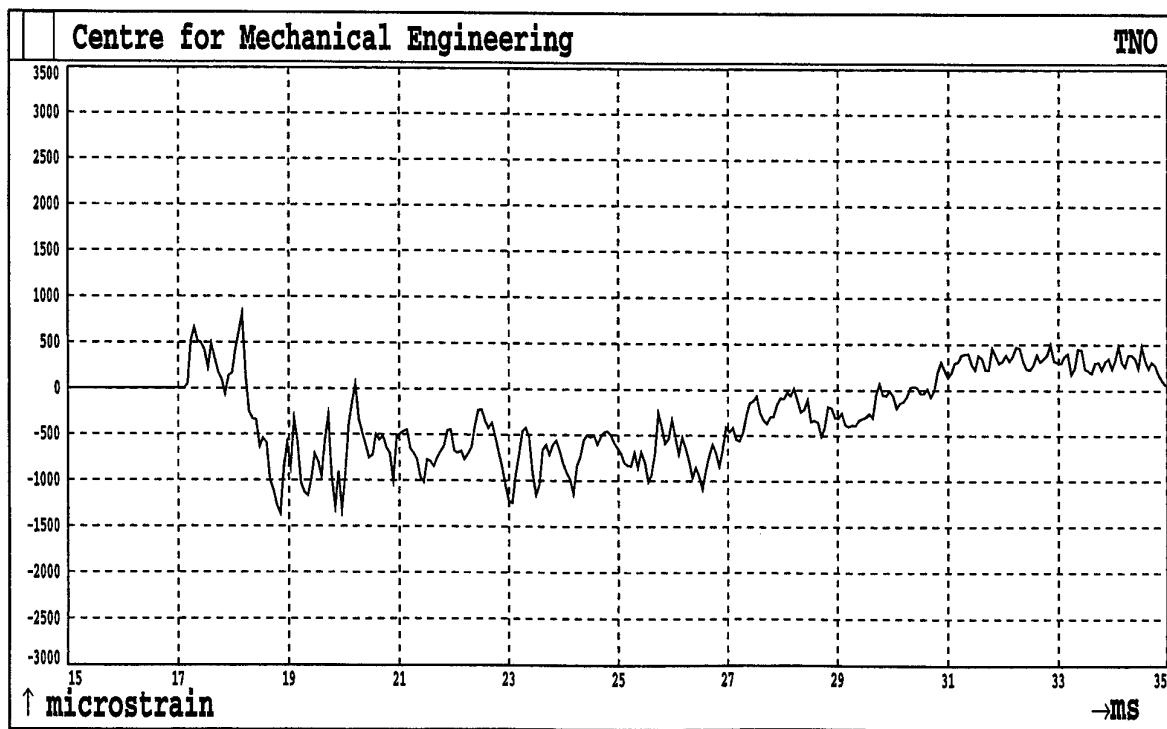
Fig.45. Shot 4   Sensor S18
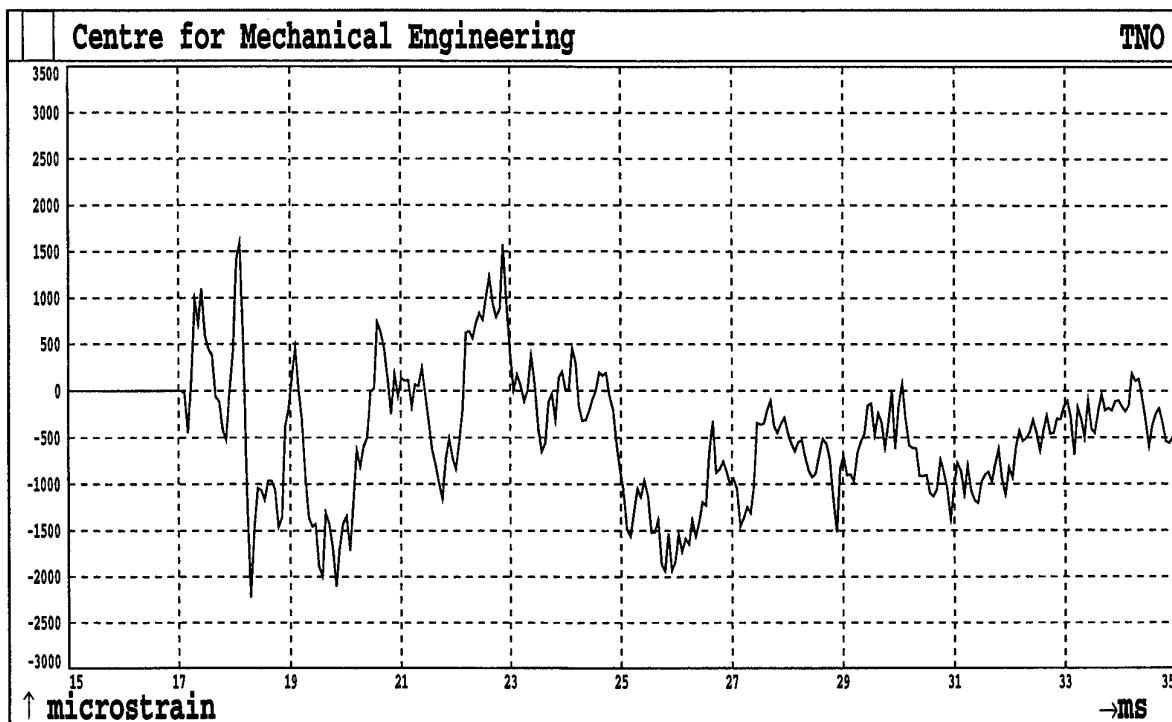
Fig.46. Shot 4　　Sensor S19

Fig.47. Shot 4　　Sensor S20

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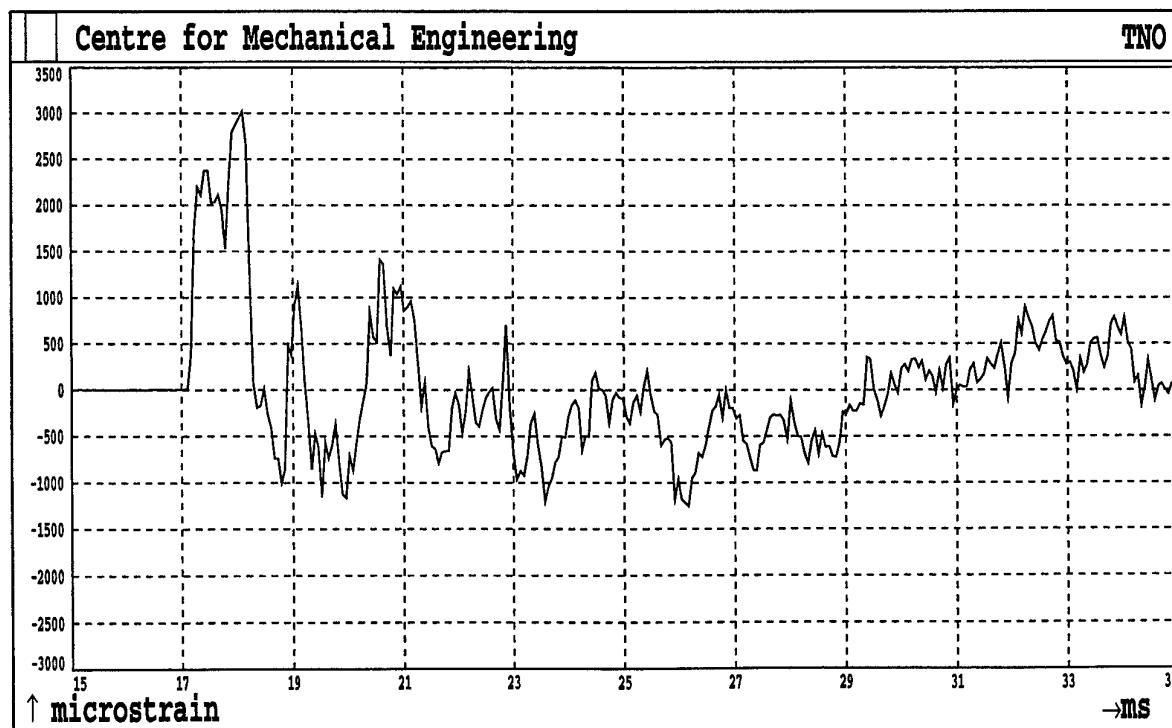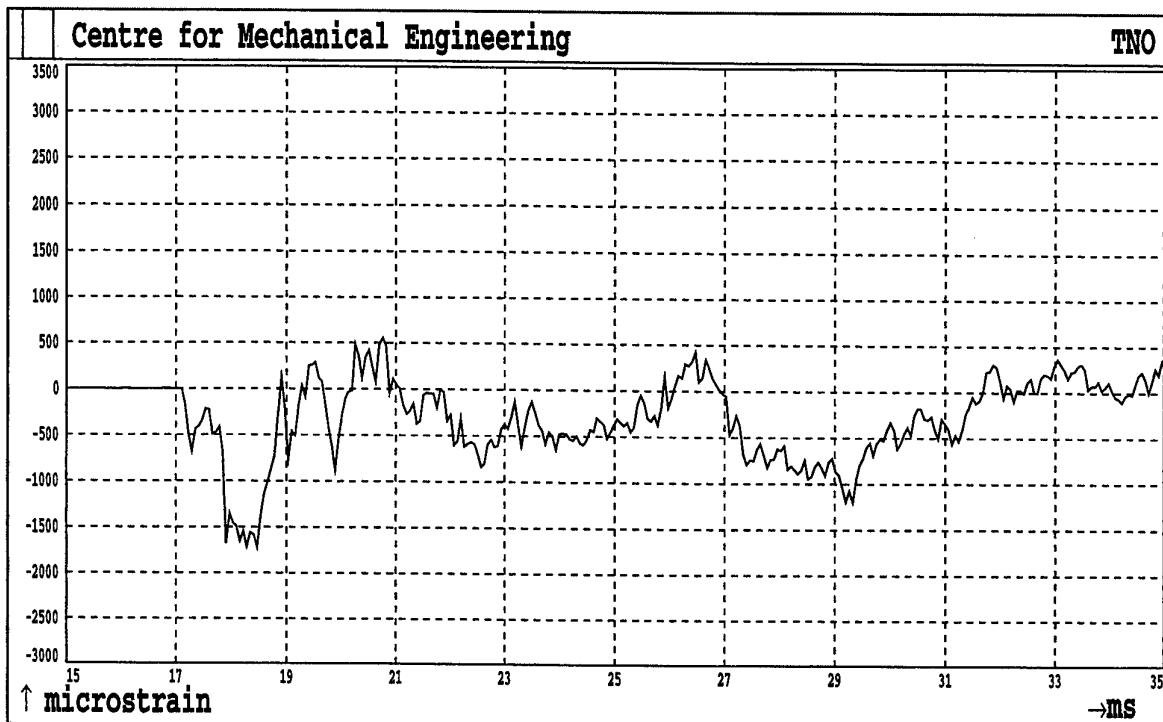
Fig.48. Shot 4   Sensor S21

Fig.49. Shot 4   Sensor S22
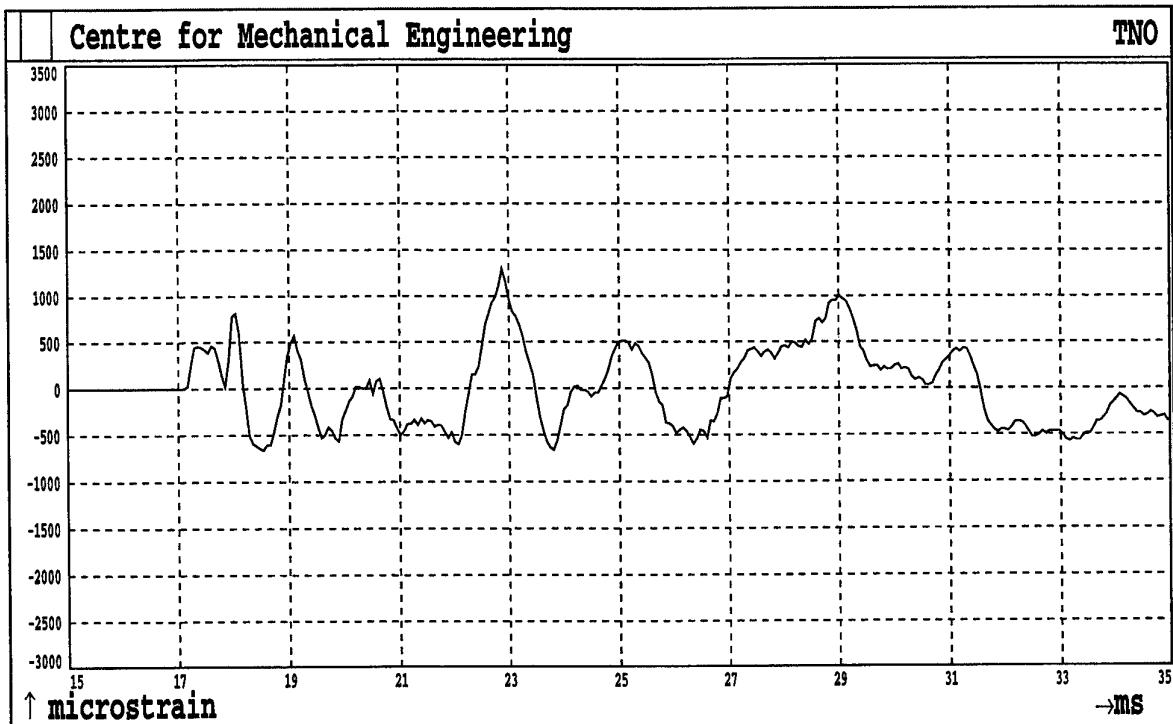
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↑ microstrain   →ms

Fig.50. Shot 4   Sensor S23

Centre for Mechanical Engineering   **TNO**

↑ microstrain   →ms

Fig.51. Shot 4   Sensor S24

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Centre for Mechanical Engineering

TNO

↑ microstrain

→ms

Fig.52. Shot 4   Sensor S25

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TNO

↑ microstrain

→ms

Fig.53. Shot 4   Sensor S26

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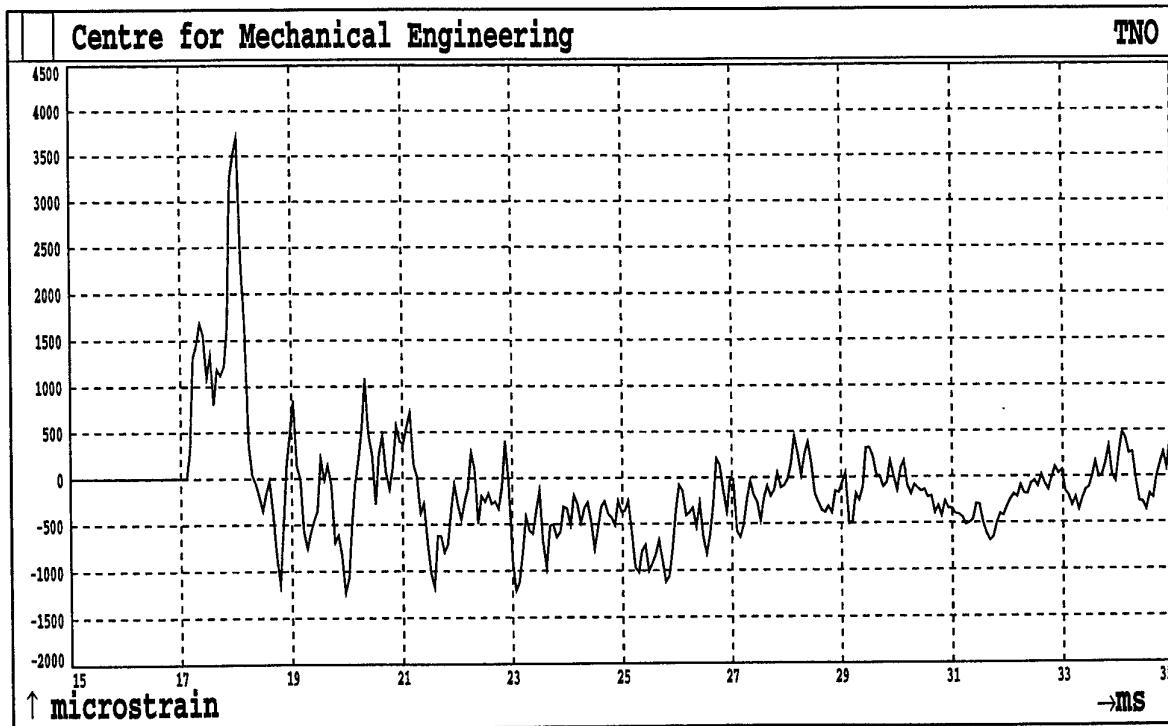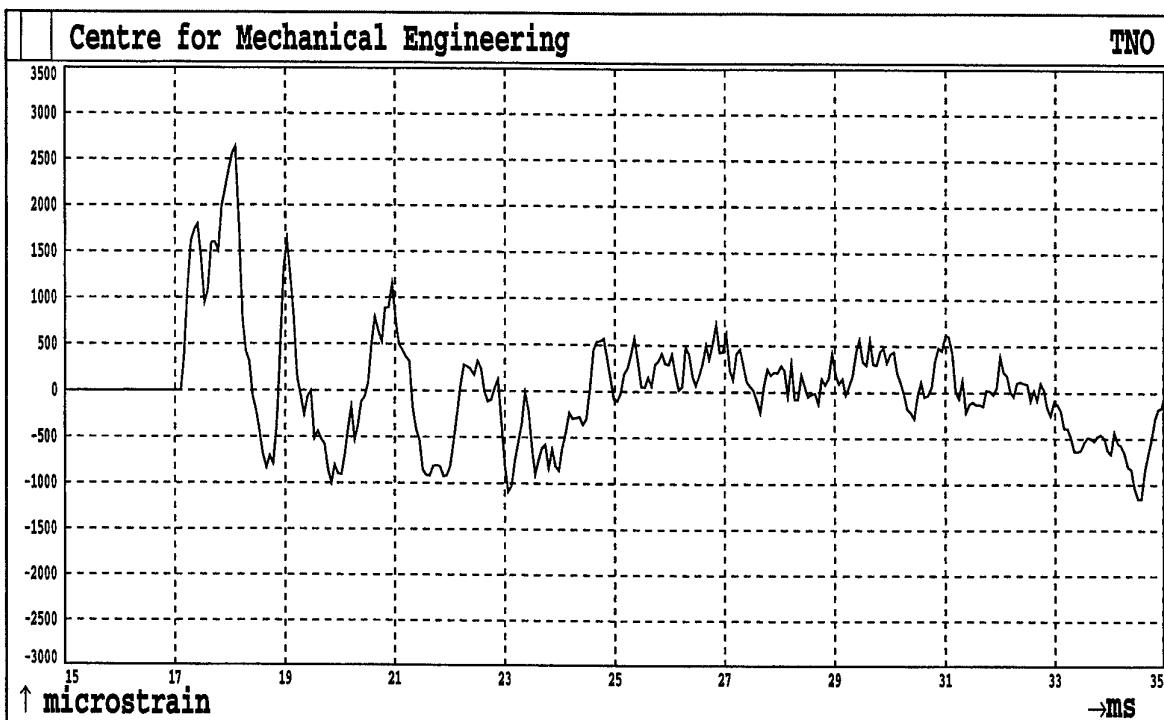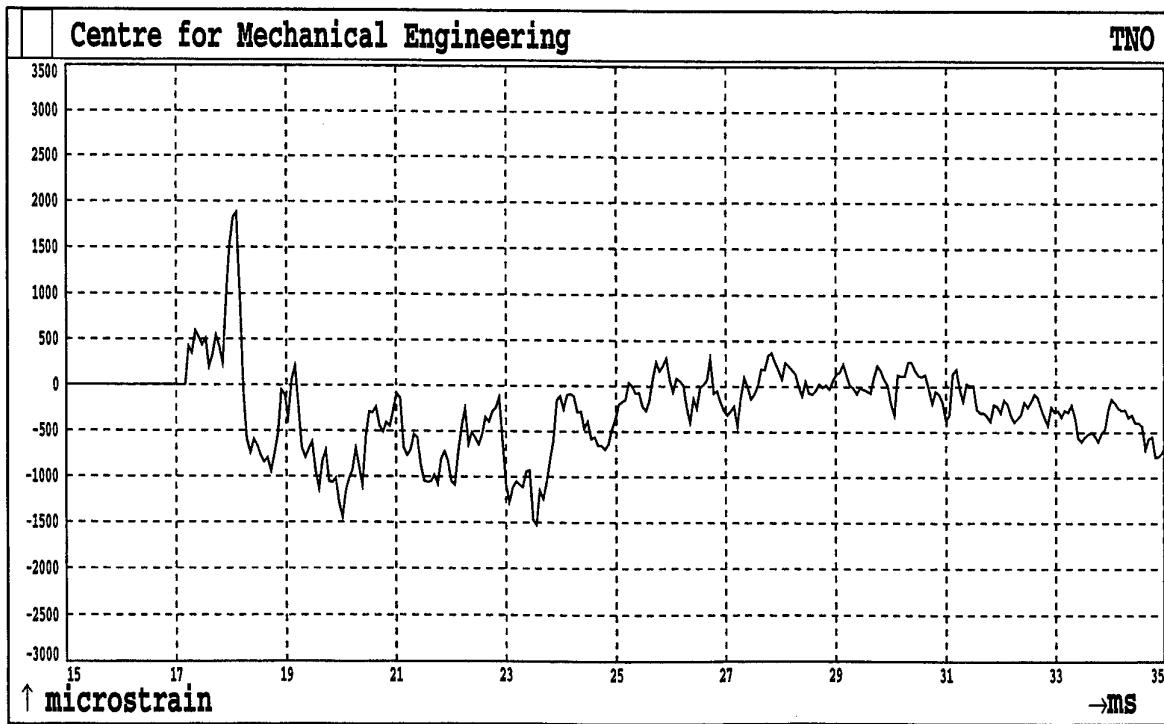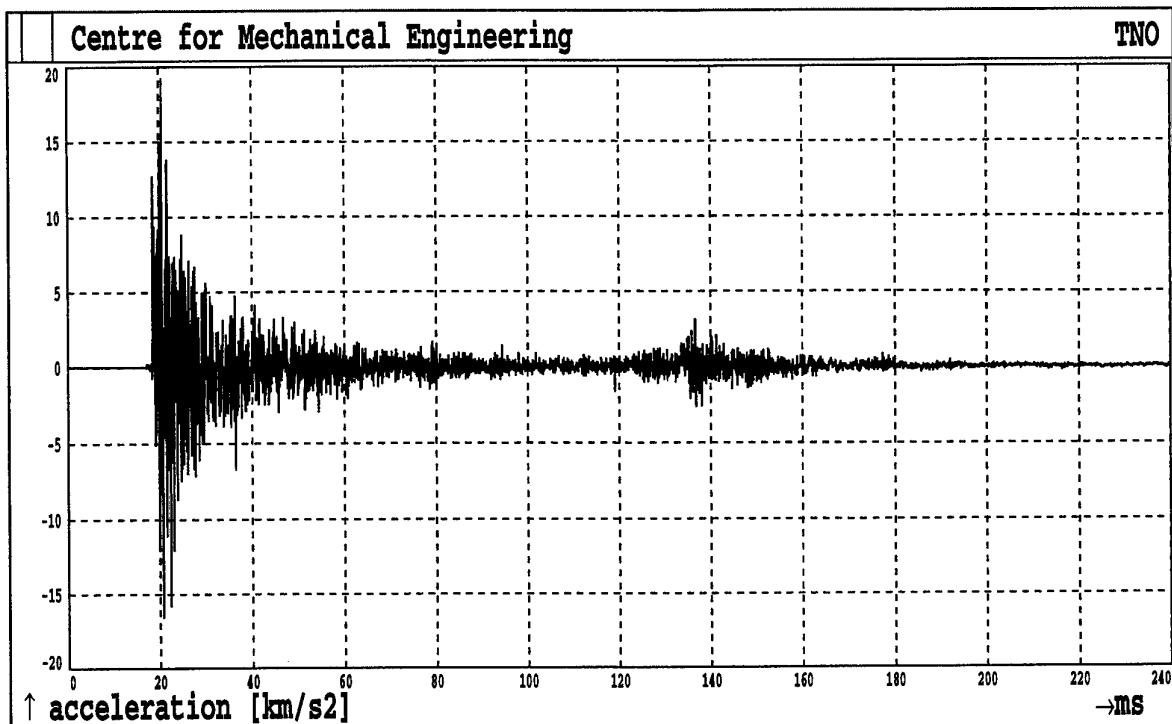
Fig.54. Shot 4 Sensor A2

Fig.55. Shot 4 Sensor A3

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Fig.56. Shot 4   Sensor A4

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Fig.57. Shot 4   Sensor A5

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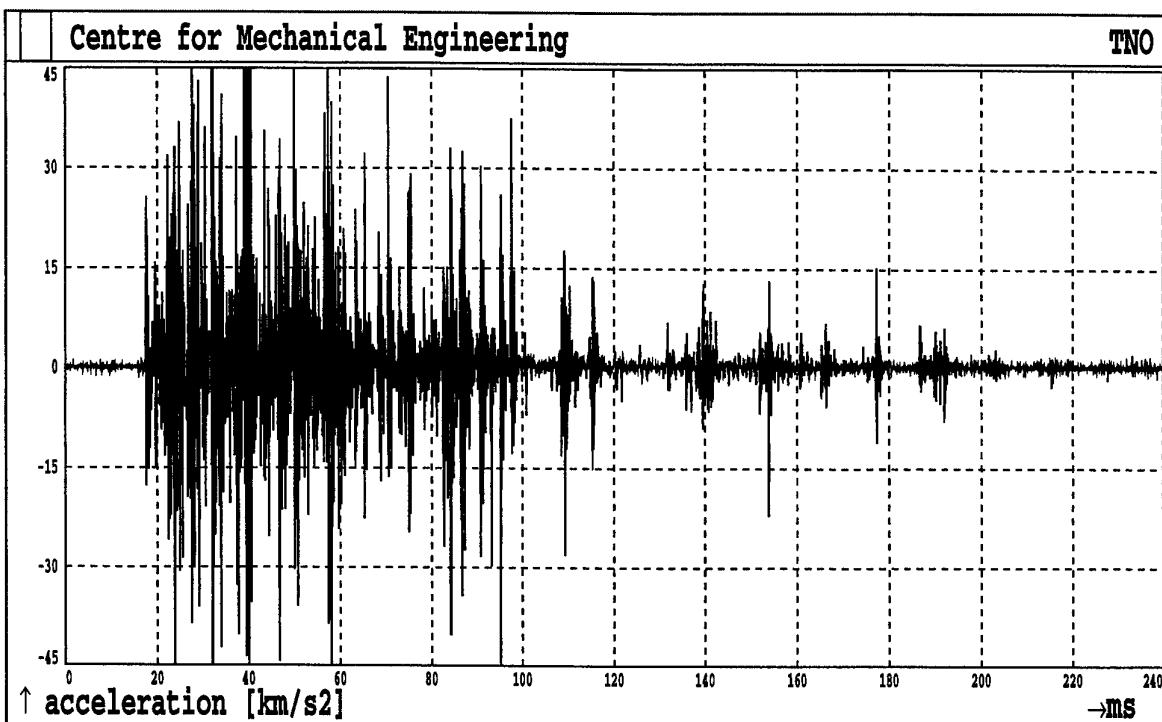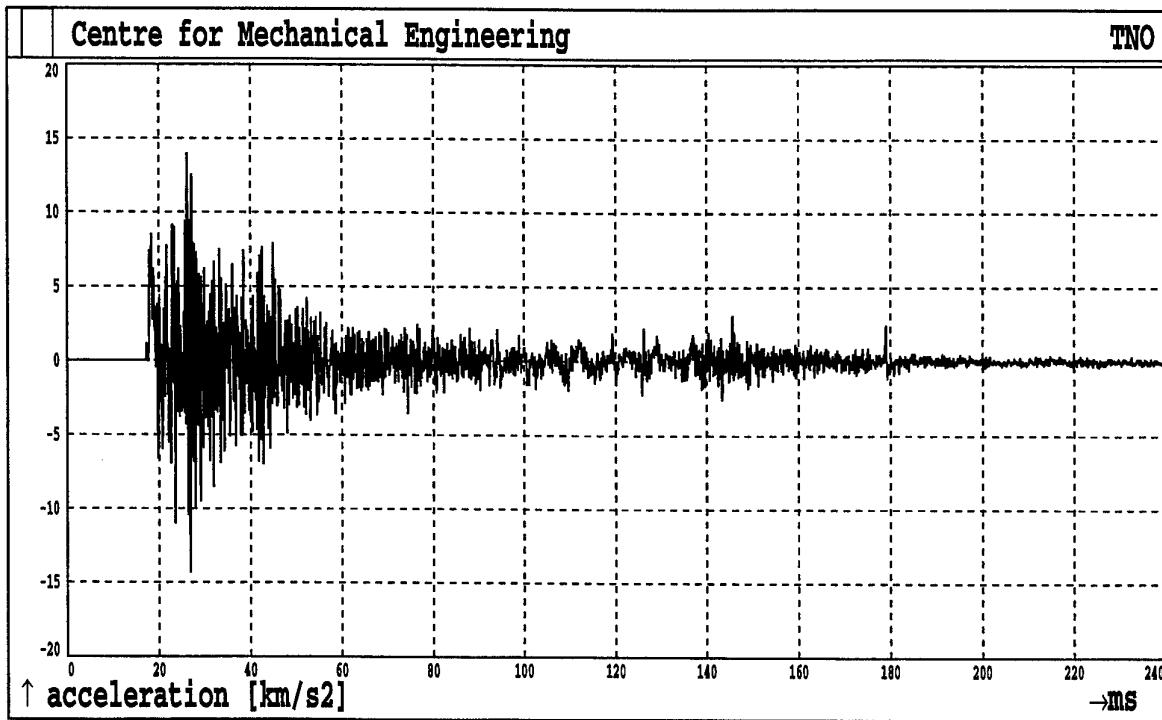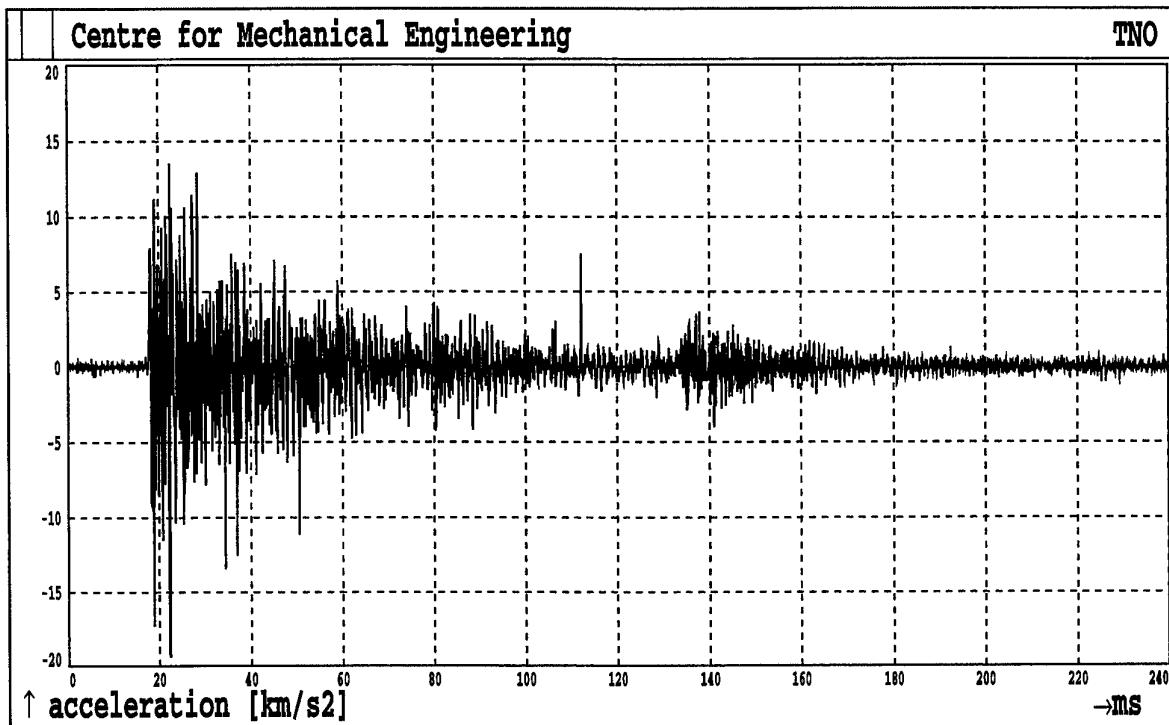
Fig.58. Shot 4 Sensor A6

Fig.59. Shot 4 Sensor A8

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Fig.60. Shot 4   Sensor A9

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Fig.61. Shot 4   Sensor A10

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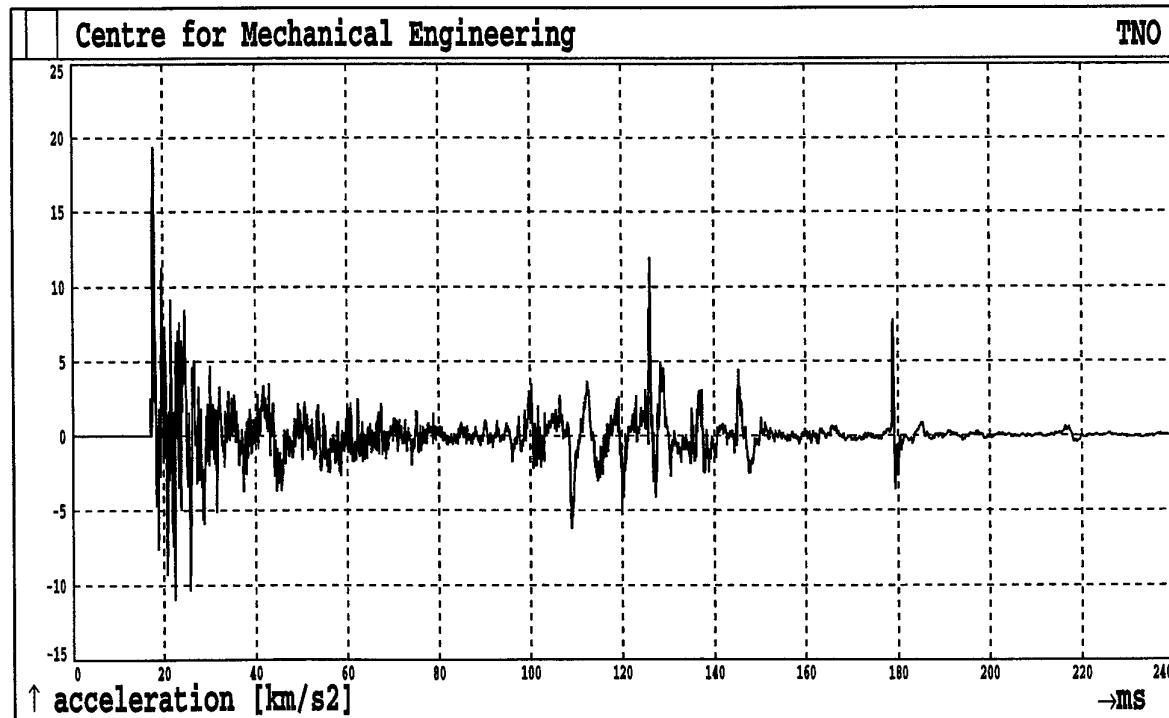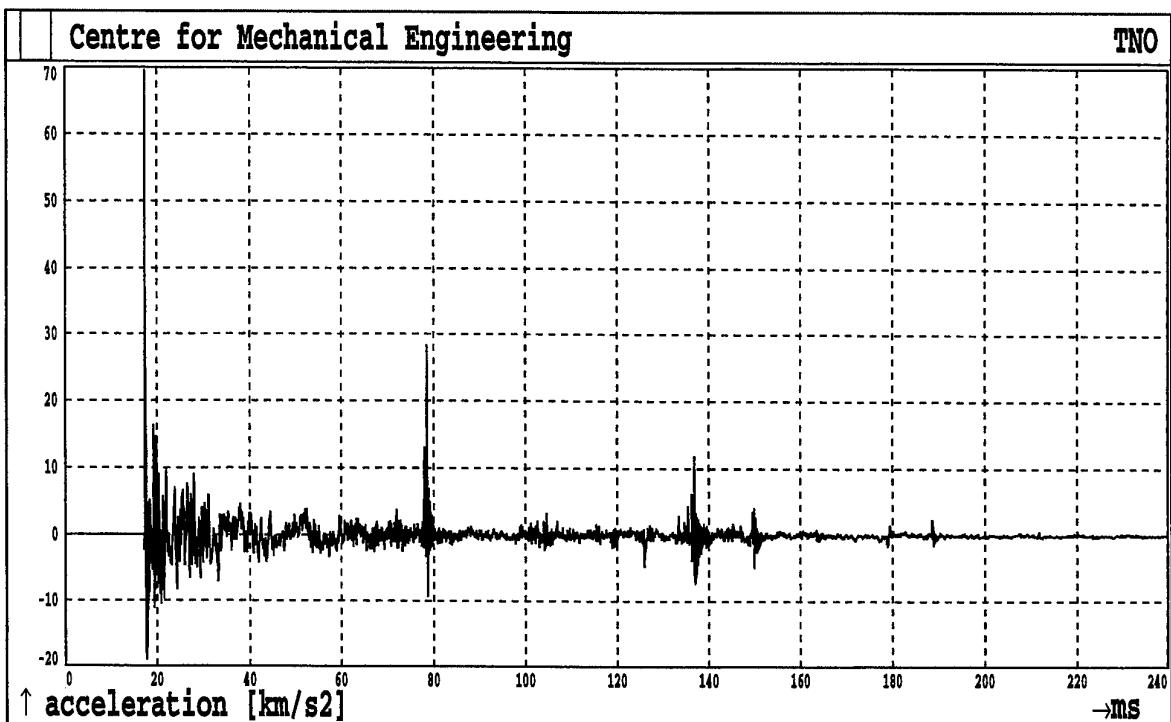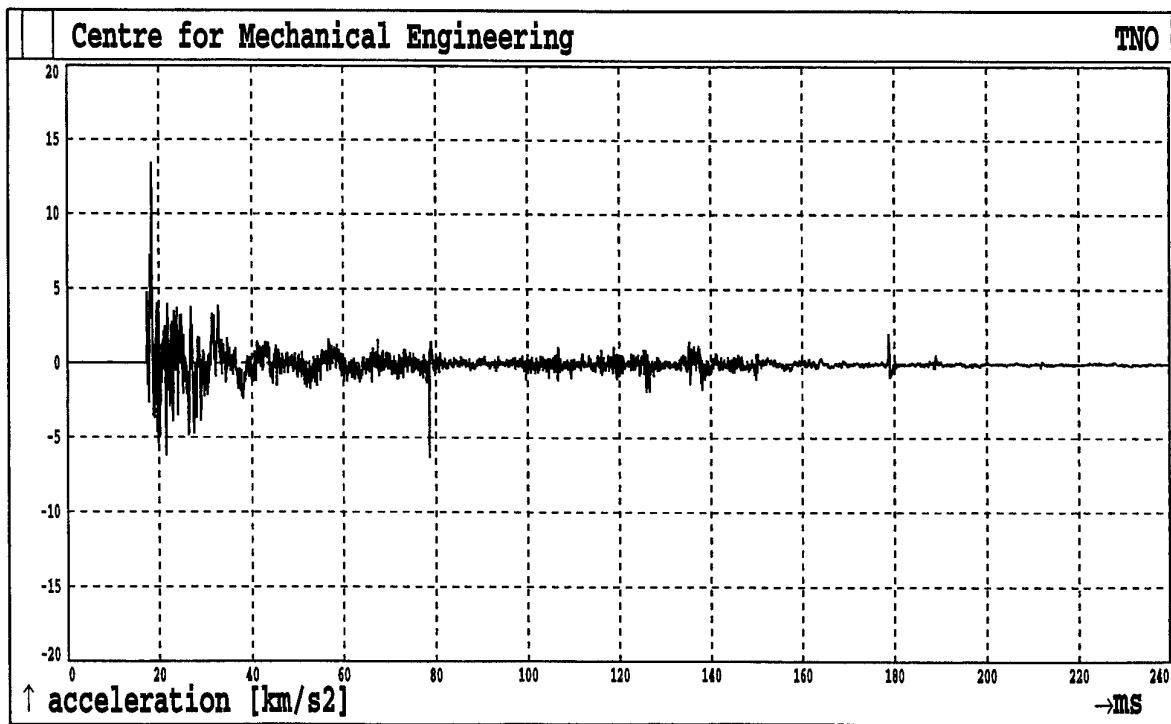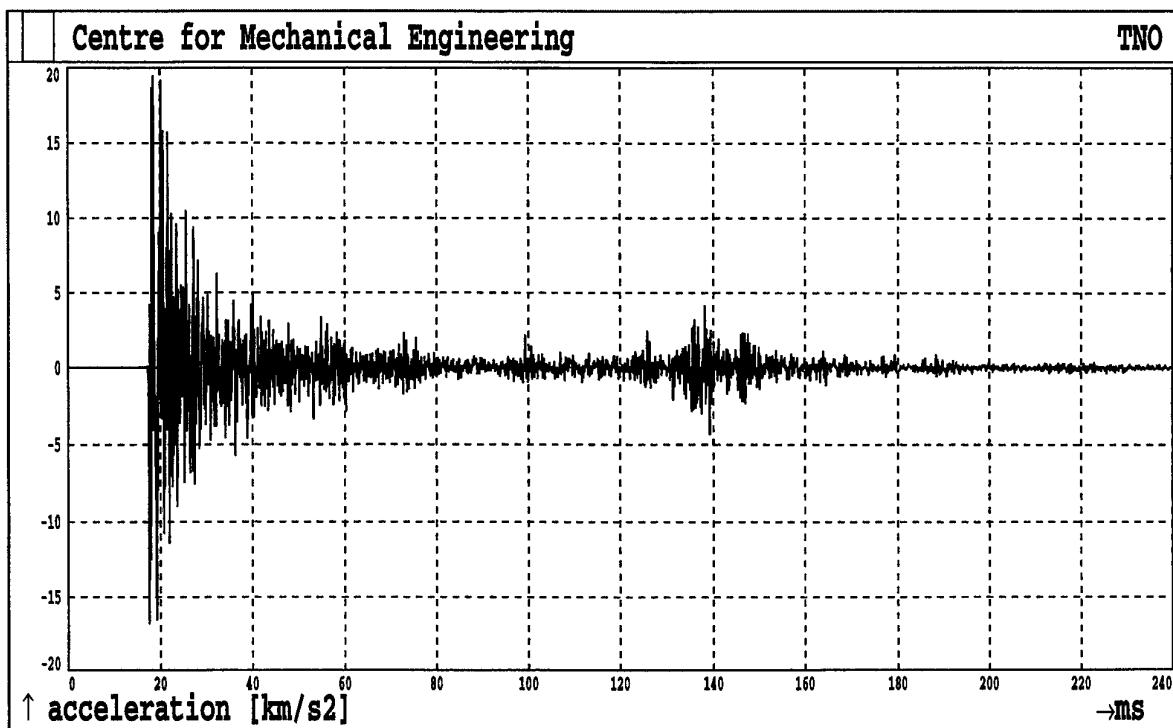
Fig.62. Shot 4   Sensor A11

Fig.63. Shot 4   Sensor A12

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↑ acceleration [km/s2]   →ms

Fig.64. Shot 4   Sensor A13

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↑ acceleration [km/s2]   →ms
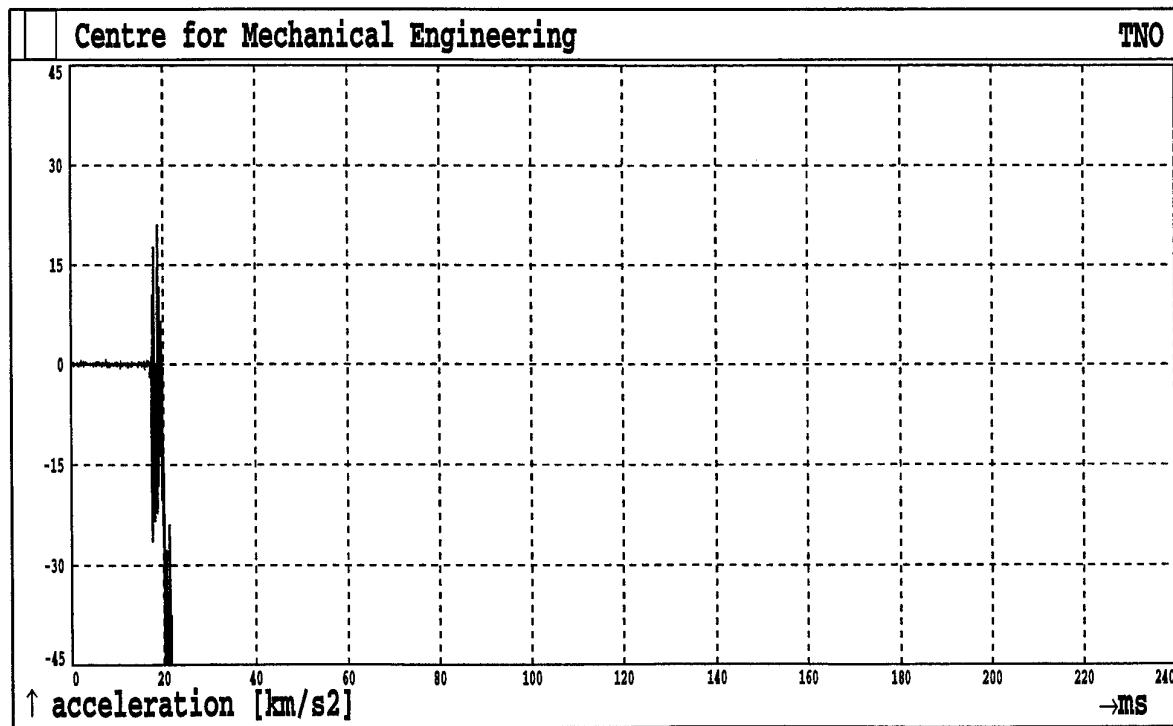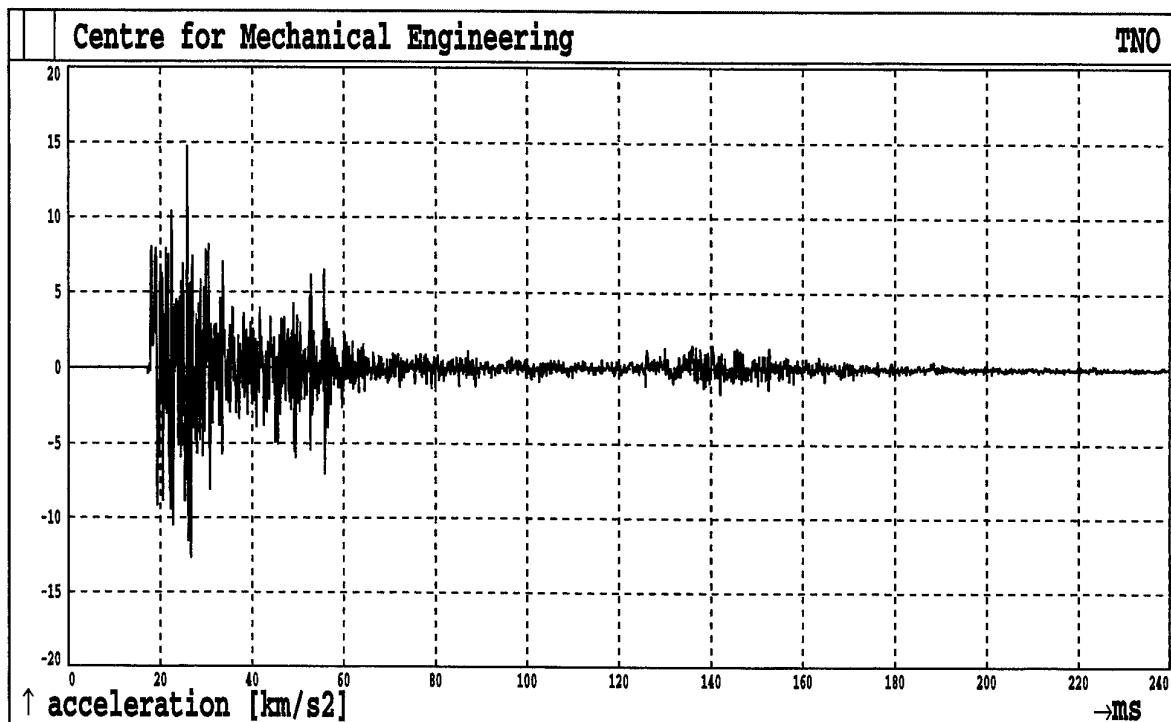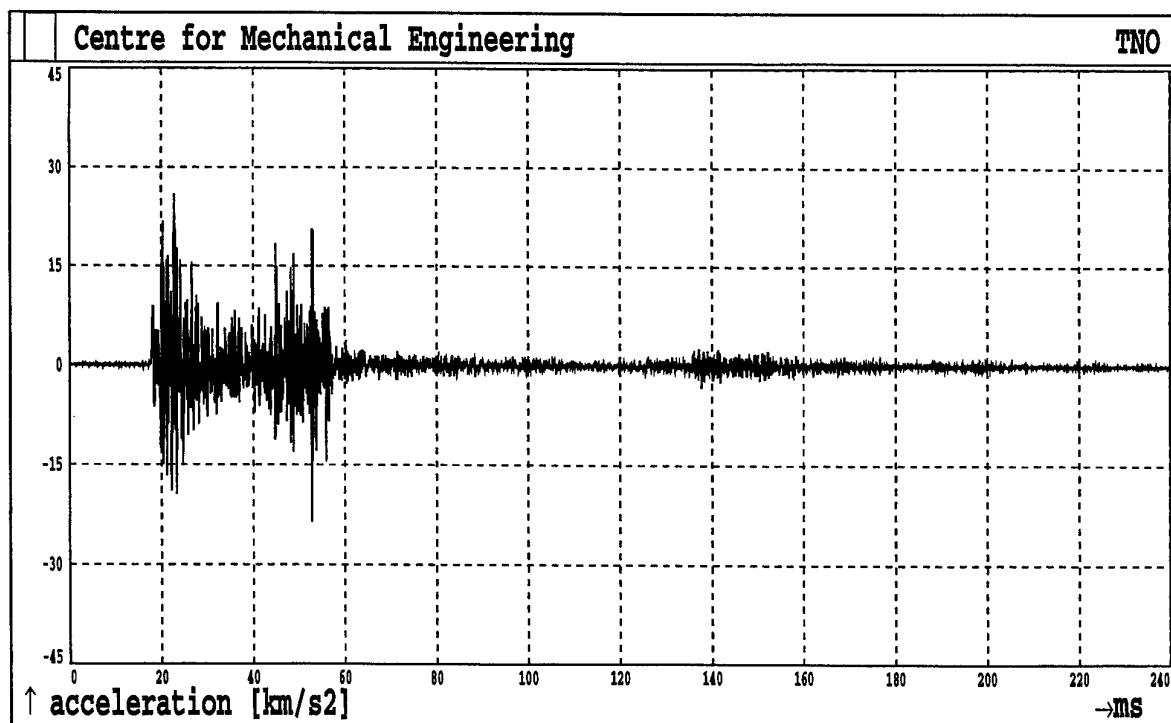
Fig.65. Shot 4   Sensor A14
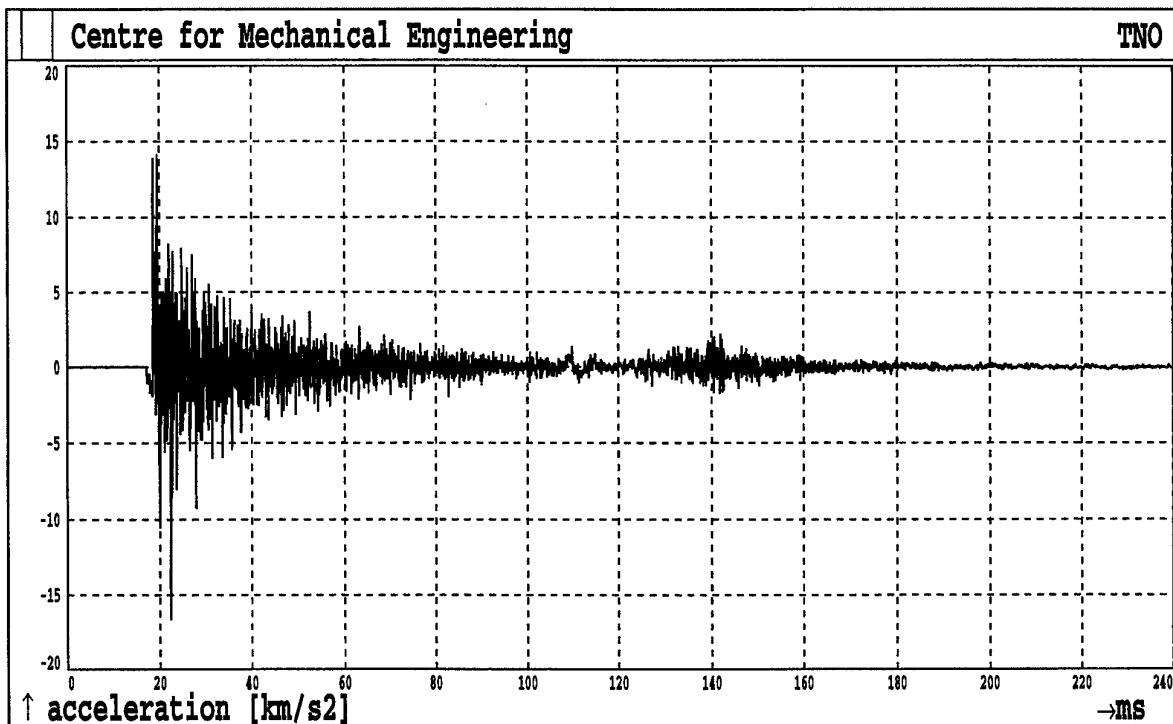
Fig.66. Shot 4   Sensor A16

Fig.67. Shot 4   Sensor A17

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Fig.68. Shot 4 Sensor A18

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Fig.69. Shot 4 Sensor A19

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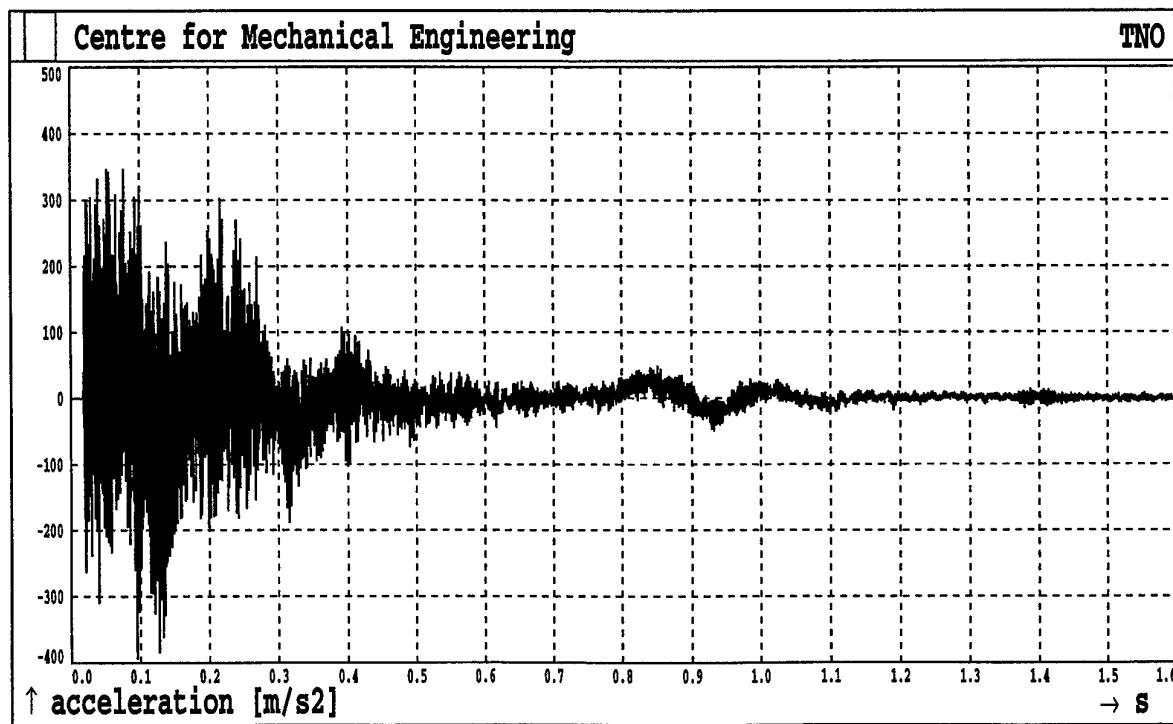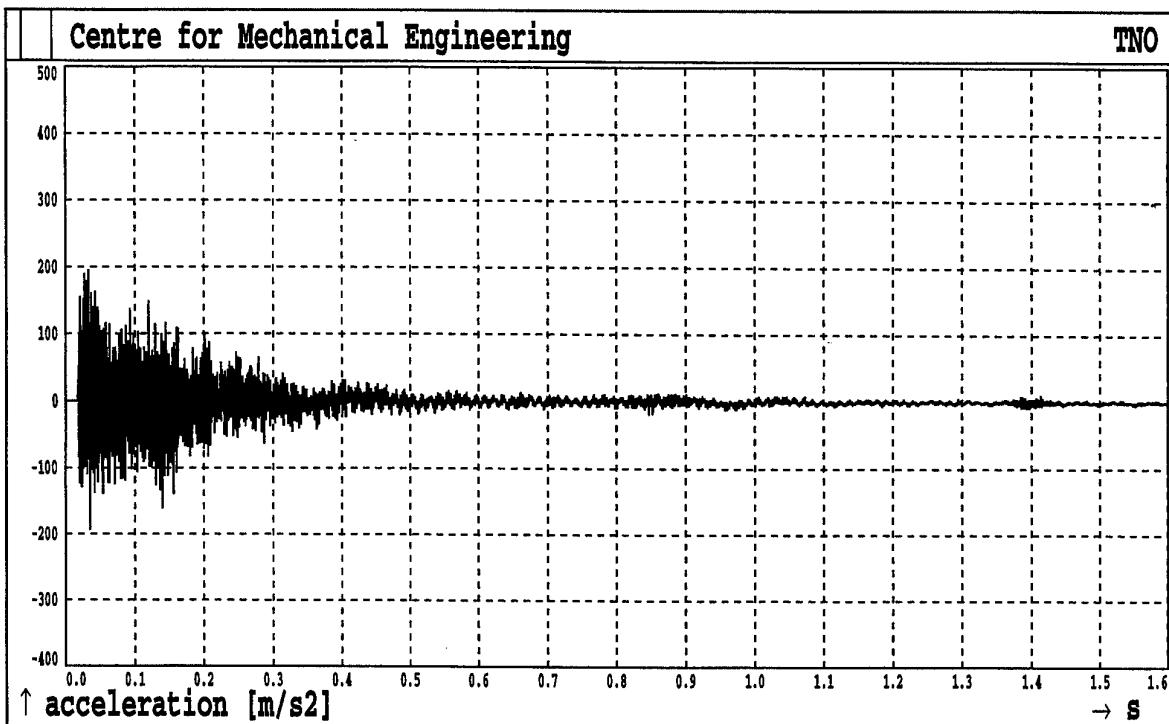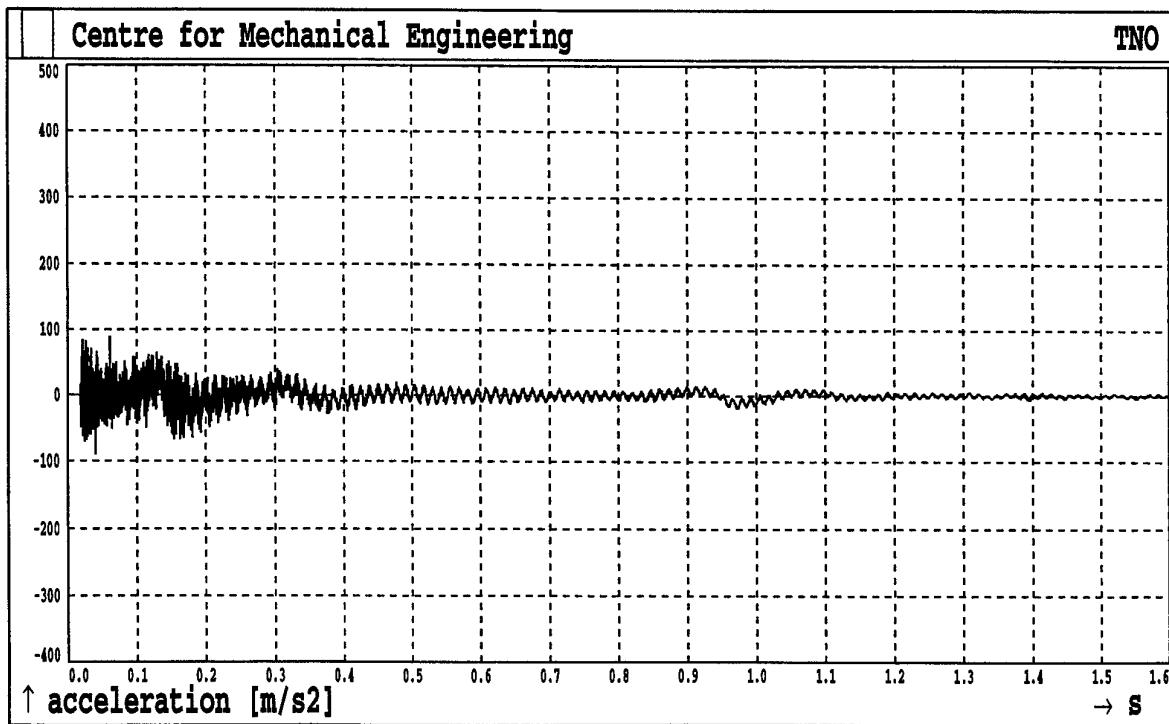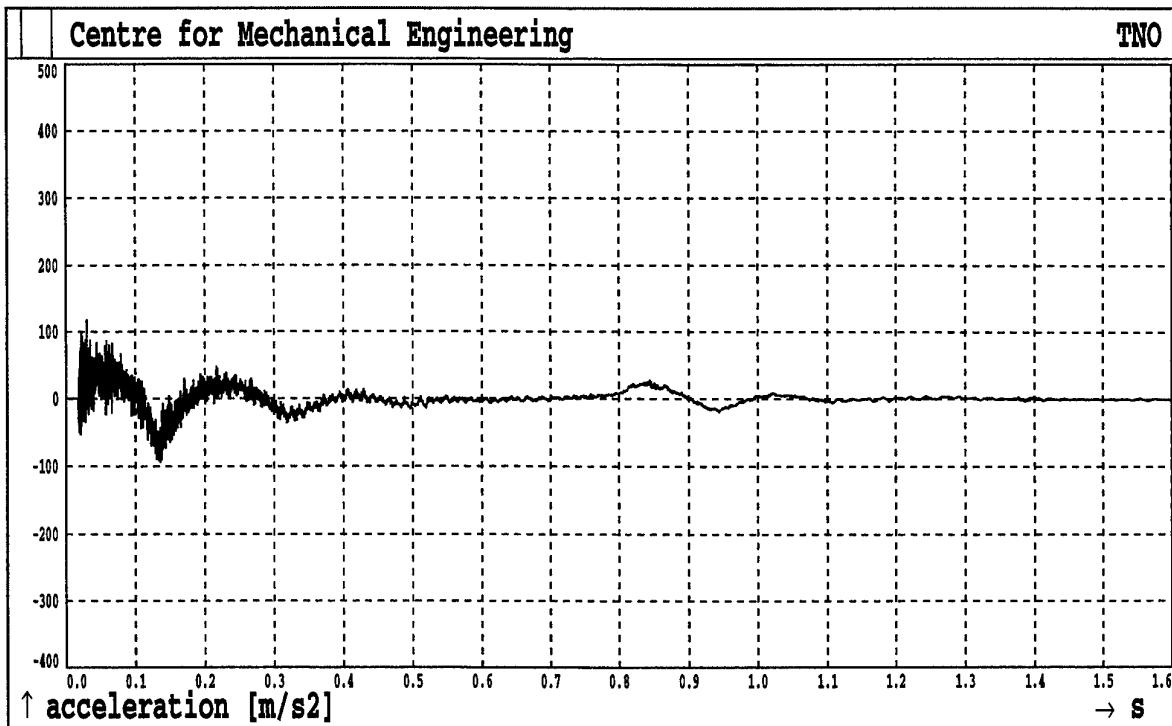
Fig.70. Shot 4   Sensor A20

Fig.71. Shot 4   Sensor A21

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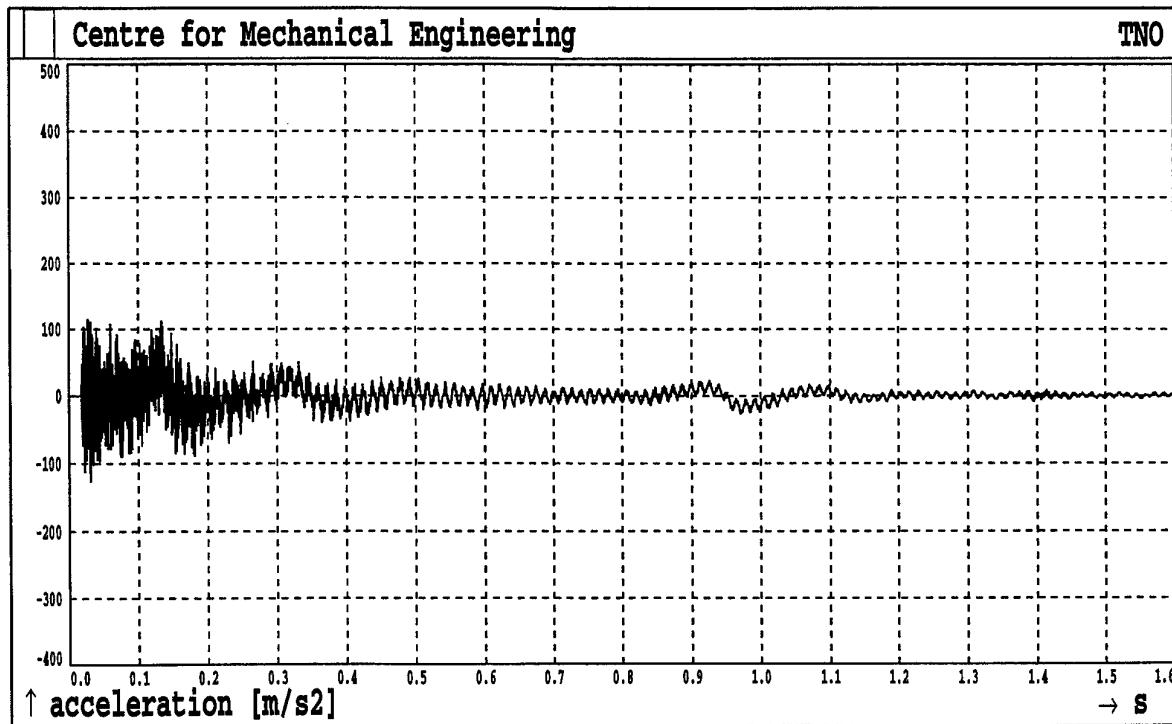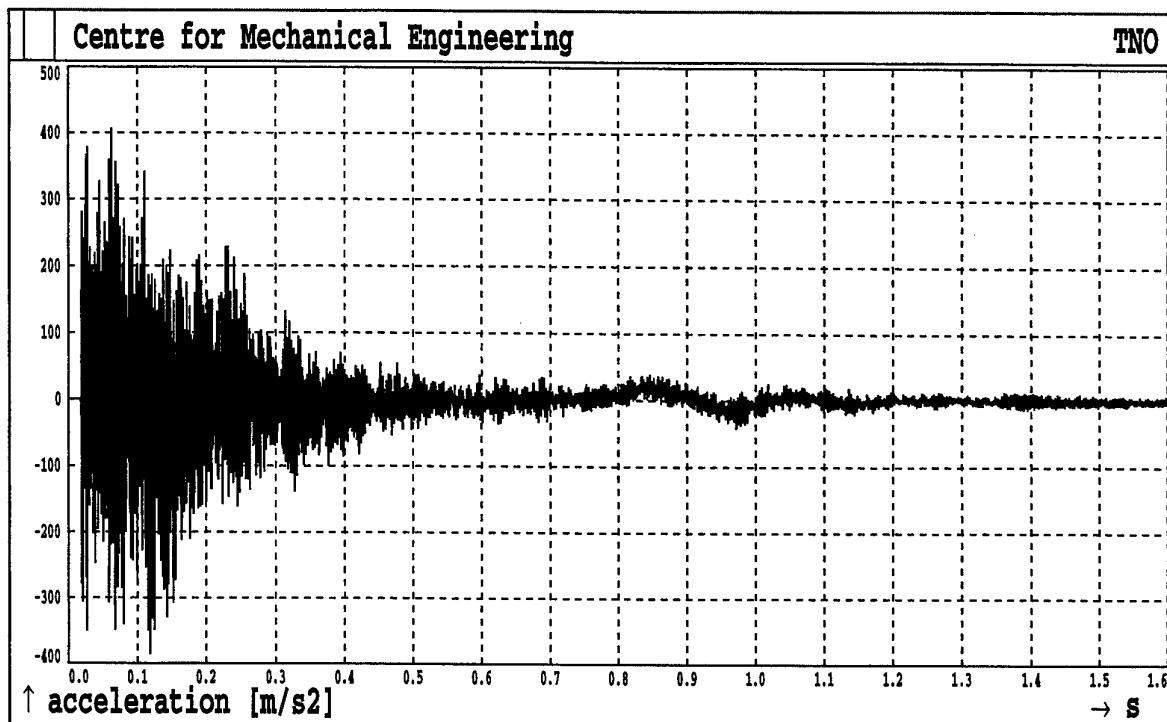
Fig.72. Shot 4   Sensor A22

Fig.73. Shot 4   Sensor A23

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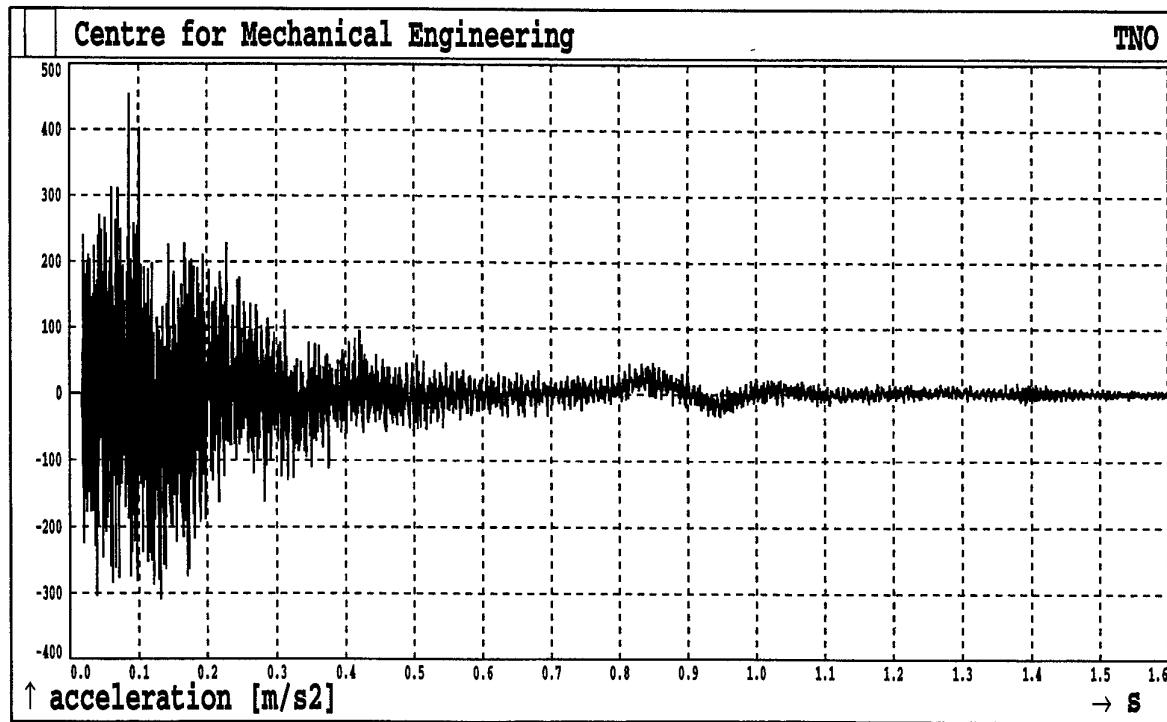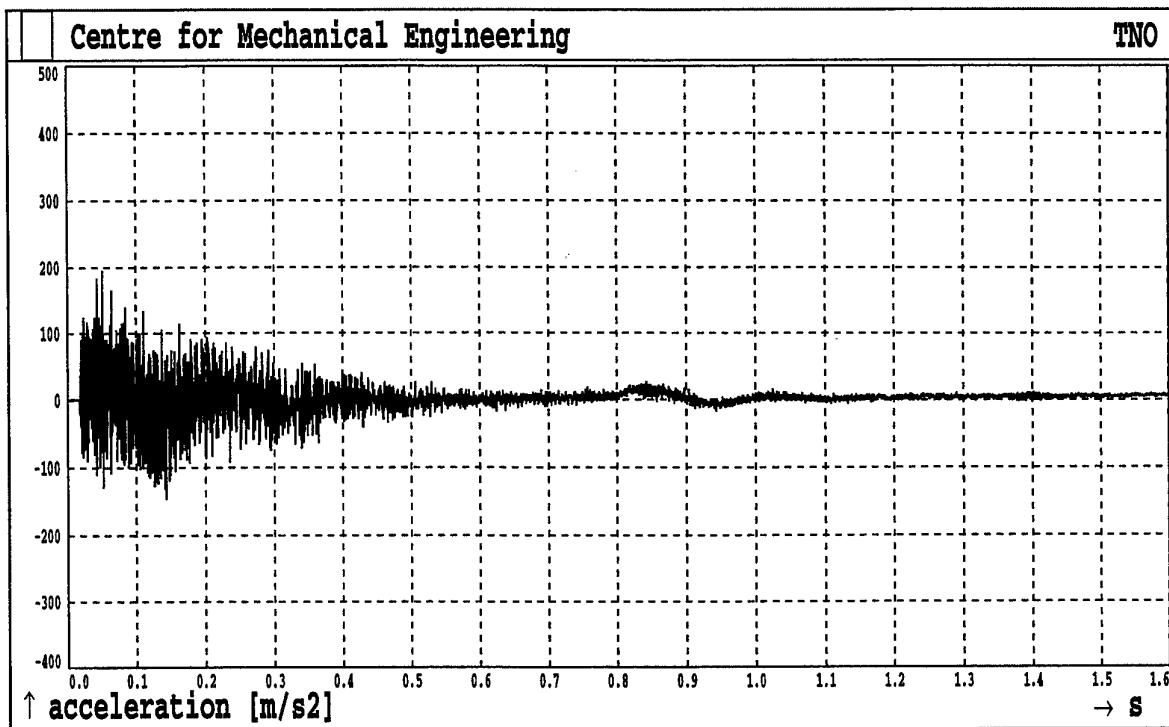
Fig.74. Shot 4   Sensor A24

Fig.75. Shot 4   Sensor A2

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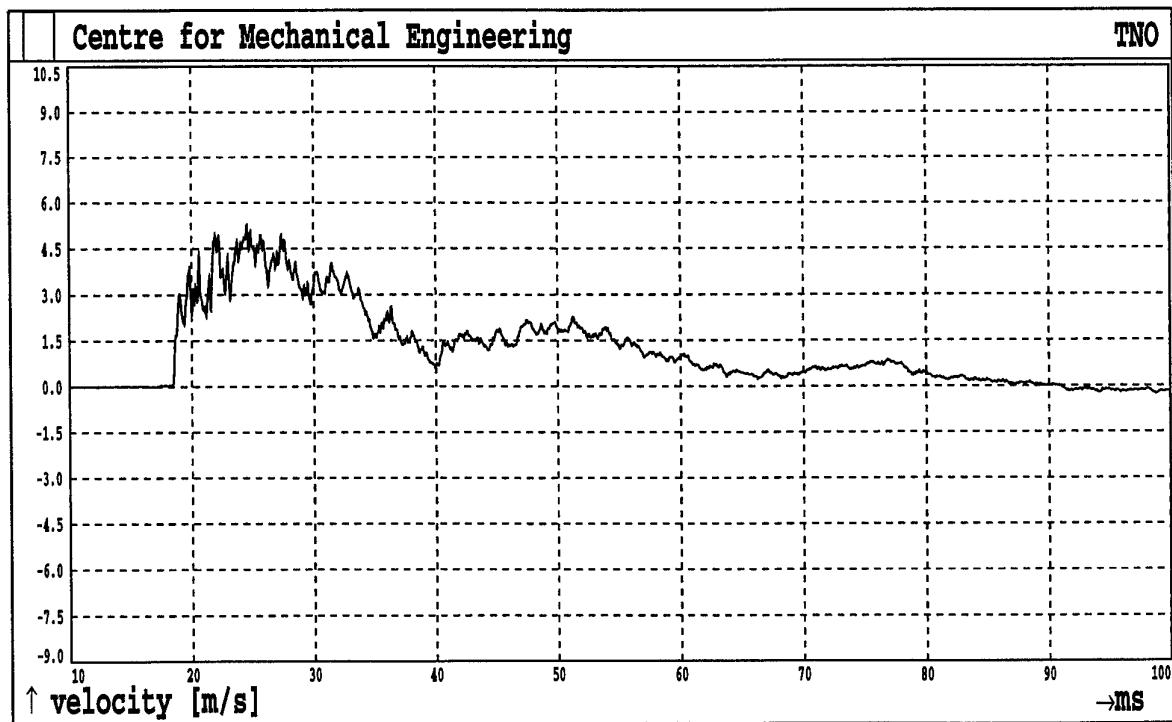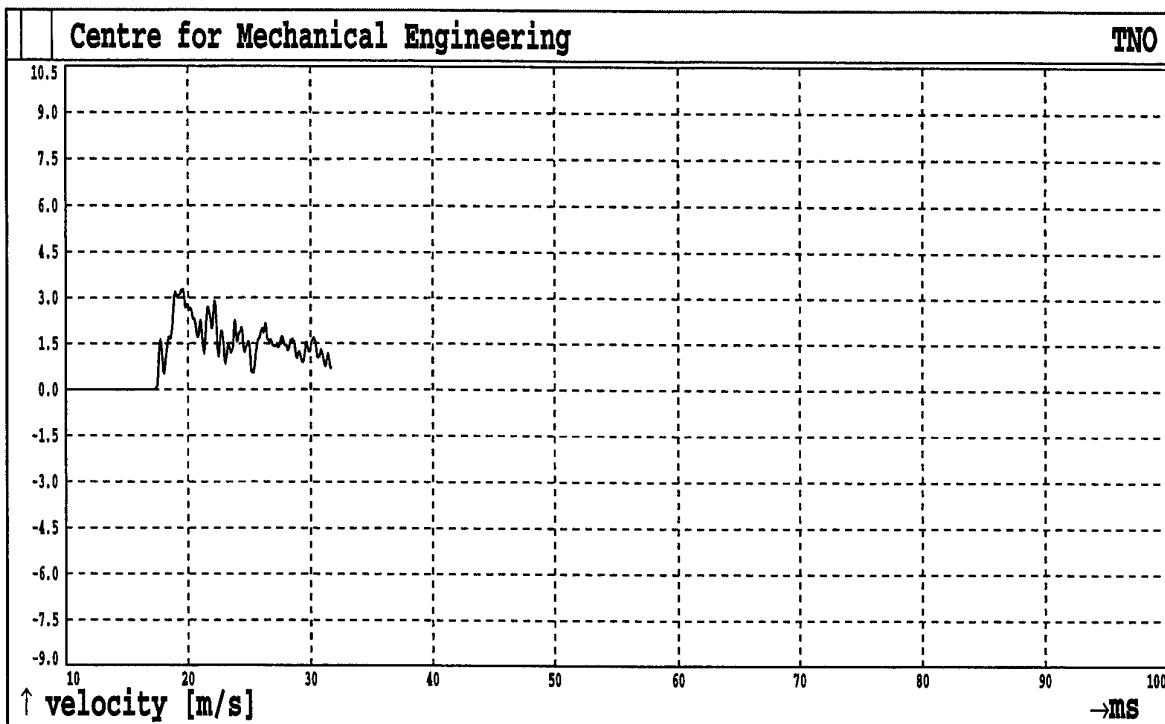
Fig.76. Shot 4   Sensor A3

Fig.77. Shot 4   Sensor A4

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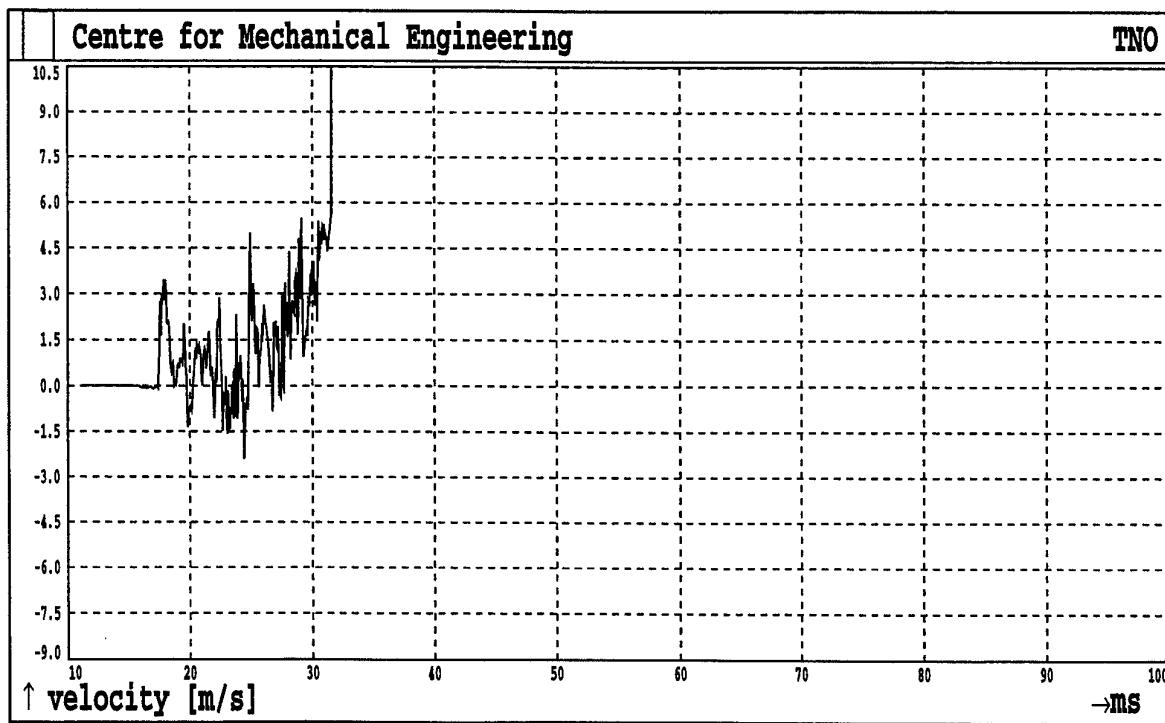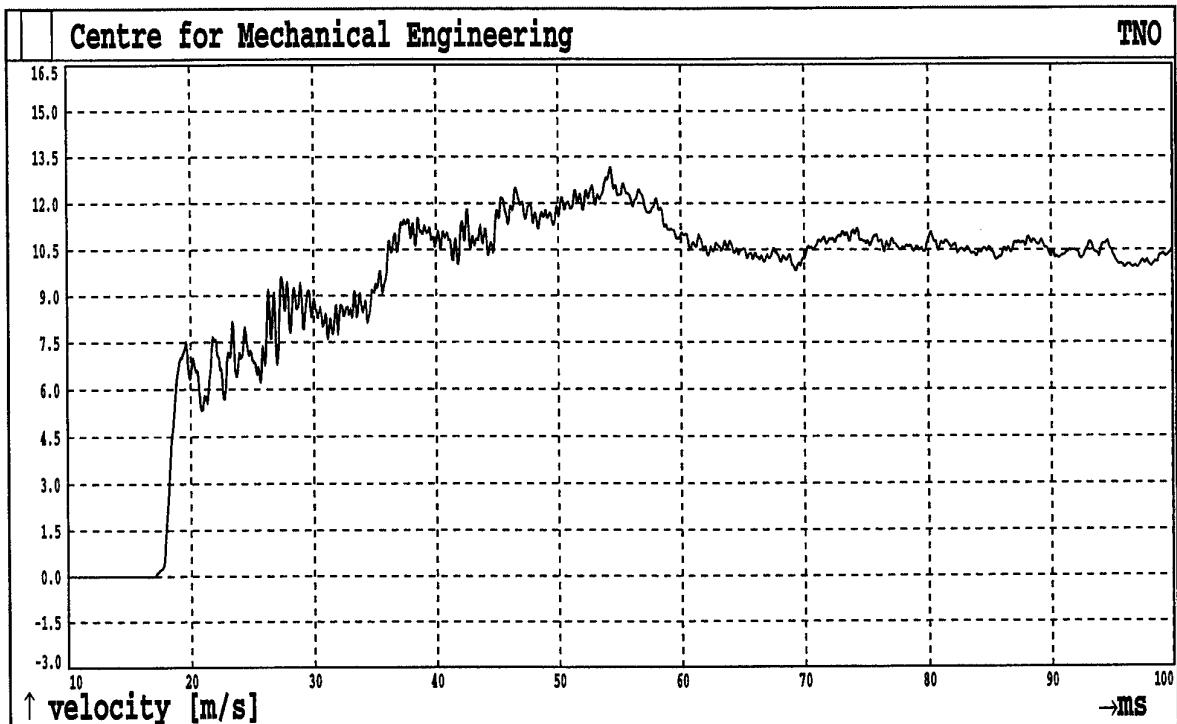
Fig.78. Shot 4 Sensor A5

Fig.79. Shot 4 Sensor A6

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↑ velocity [m/s]　　　　　　　　　　　　　→ms

Fig.80. Shot 4　Sensor A8

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↑ velocity [m/s]　　　　　　　　　　　　　→ms

Fig.81. Shot 4　Sensor A9

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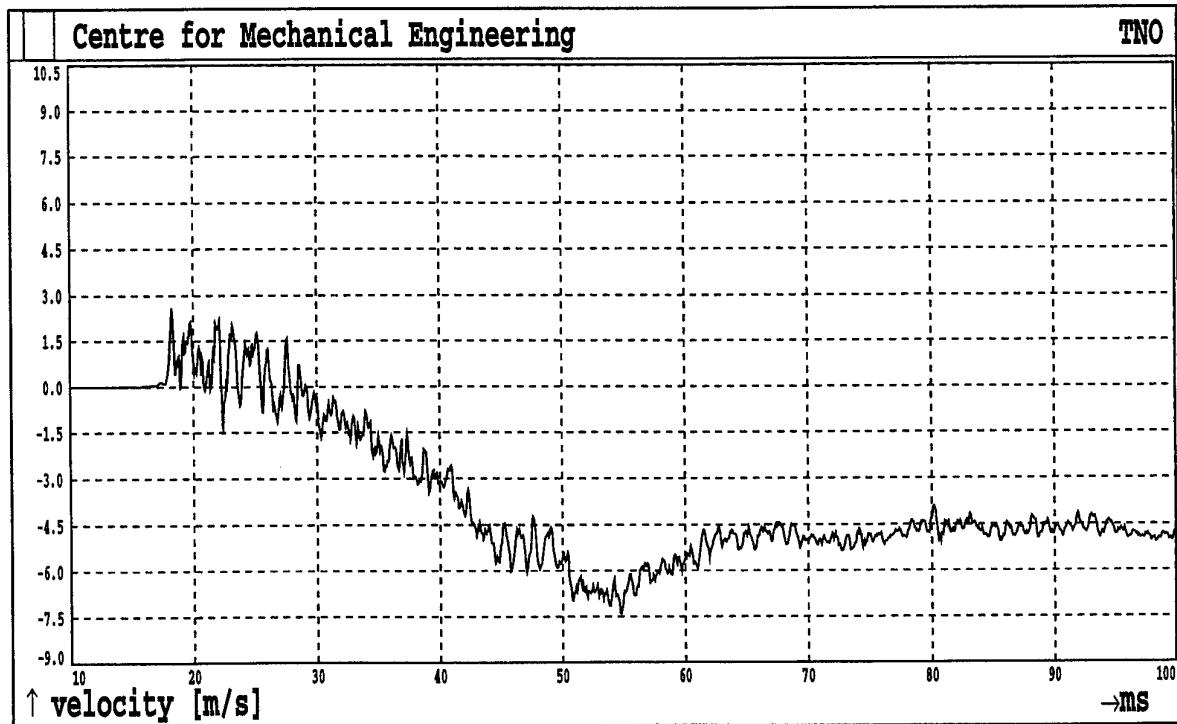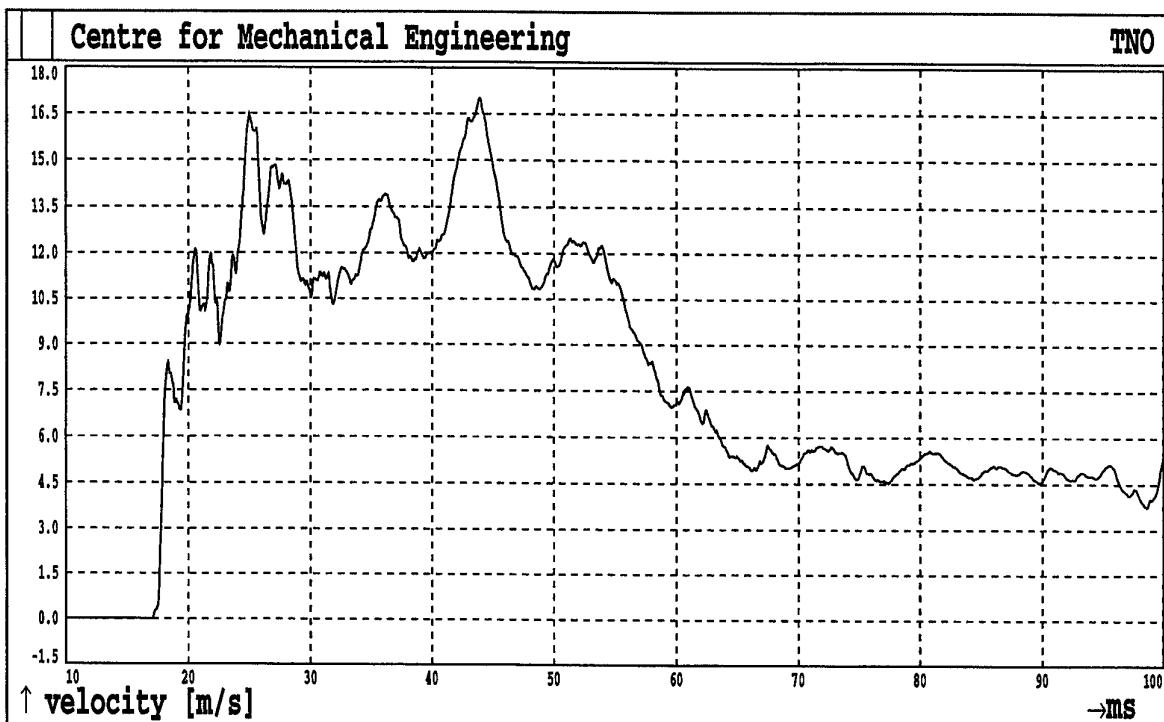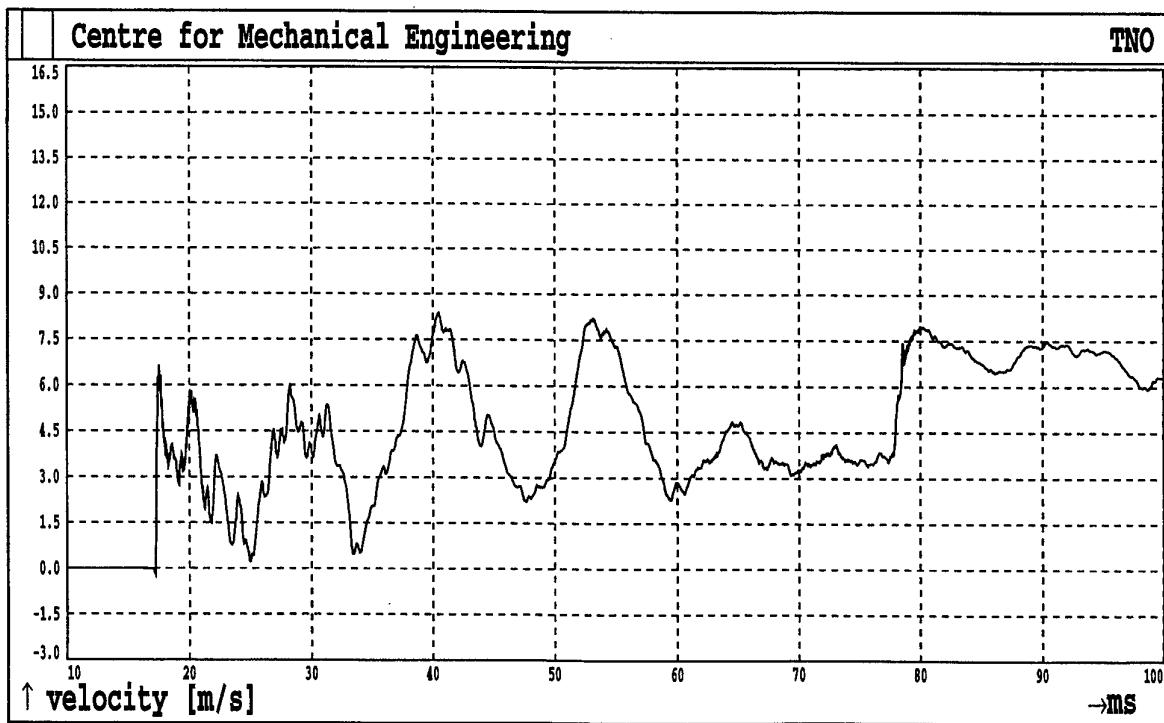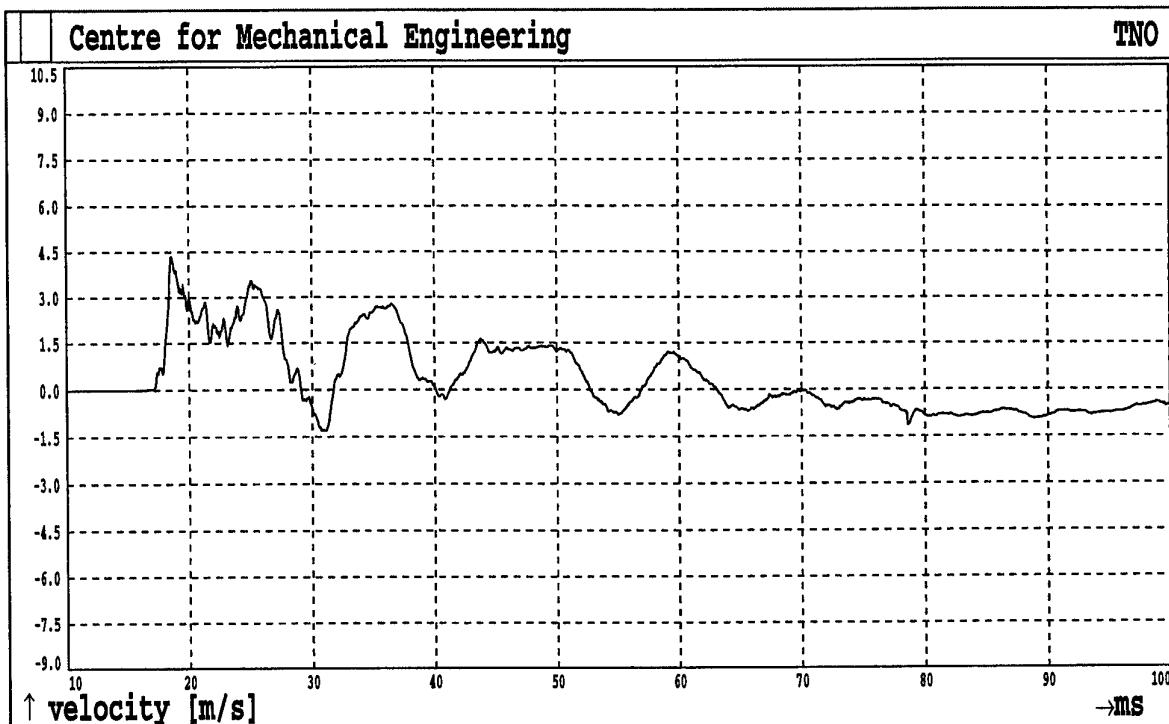
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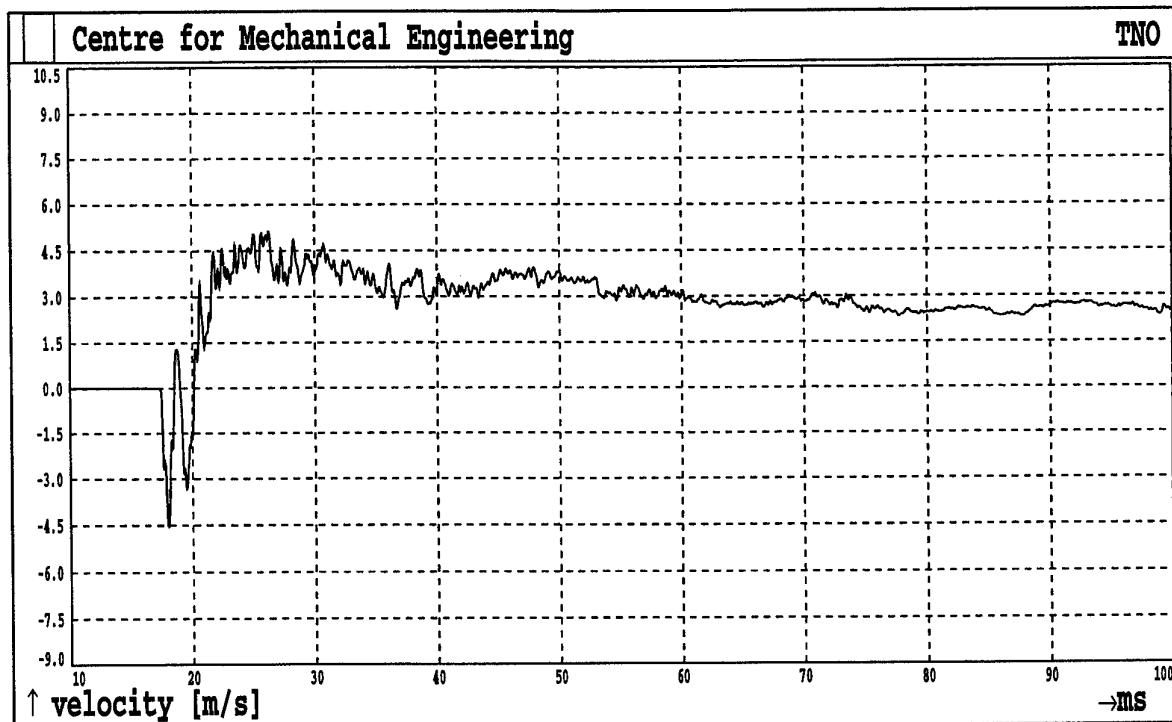
Fig.83. Shot 4 Sensor A11
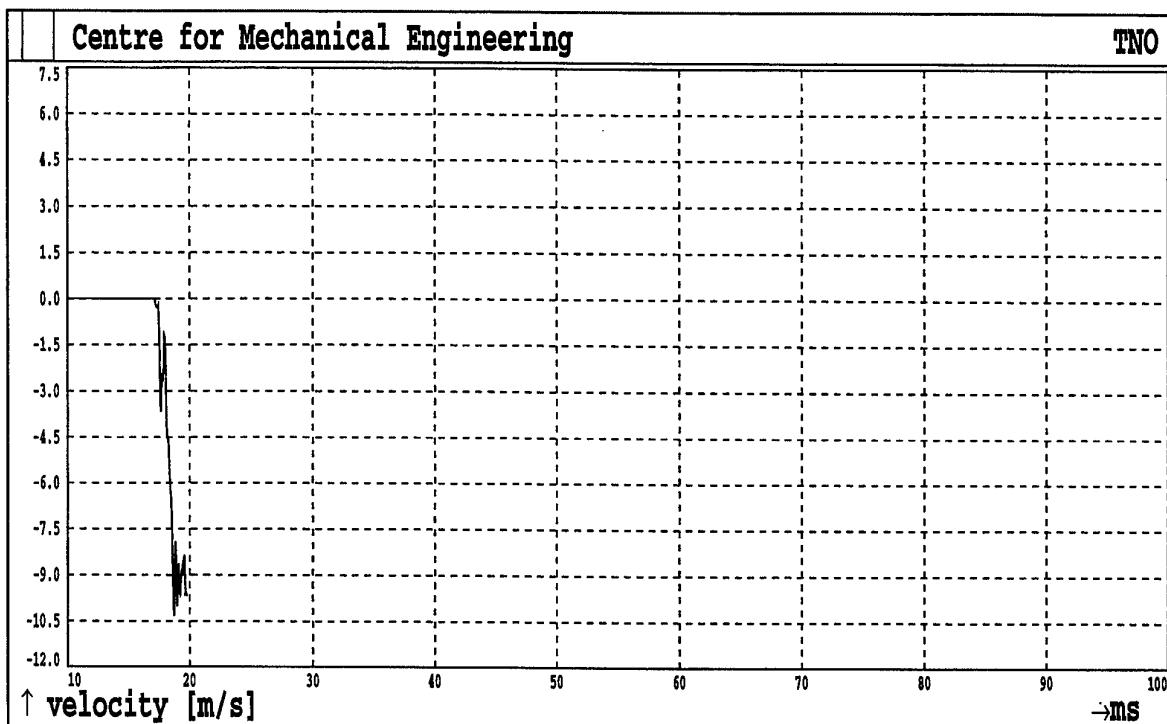
Fig.84. Shot 4 Sensor A12
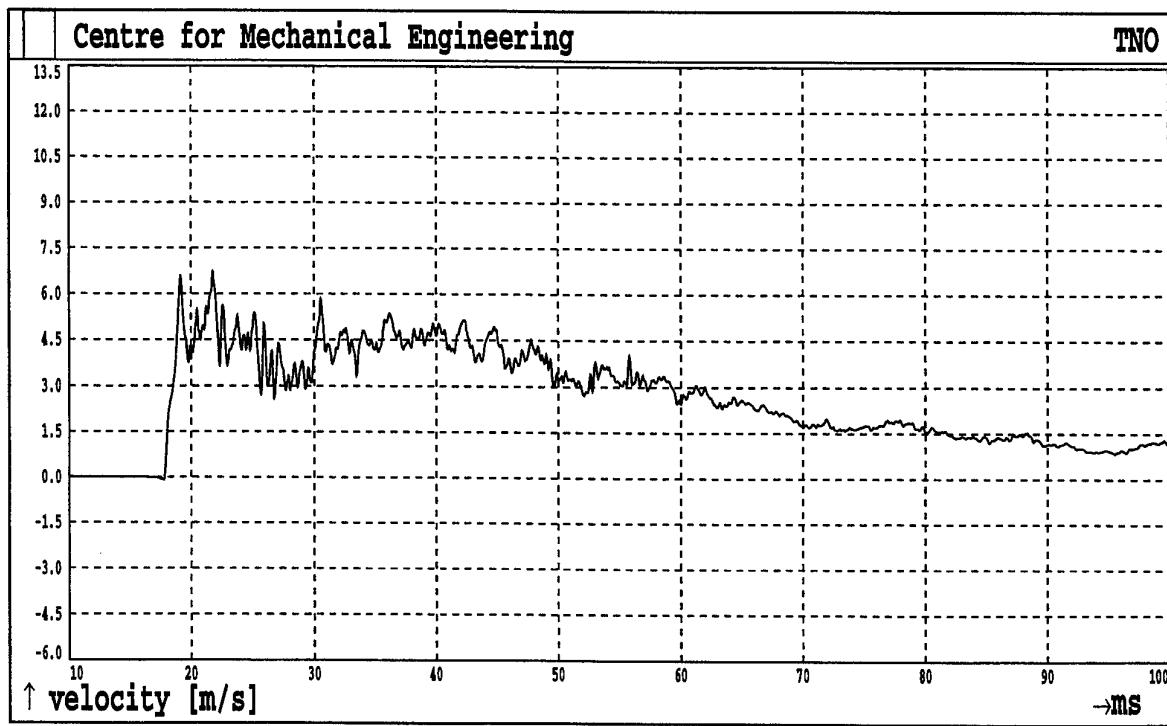
Fig.85. Shot 4 Sensor A13
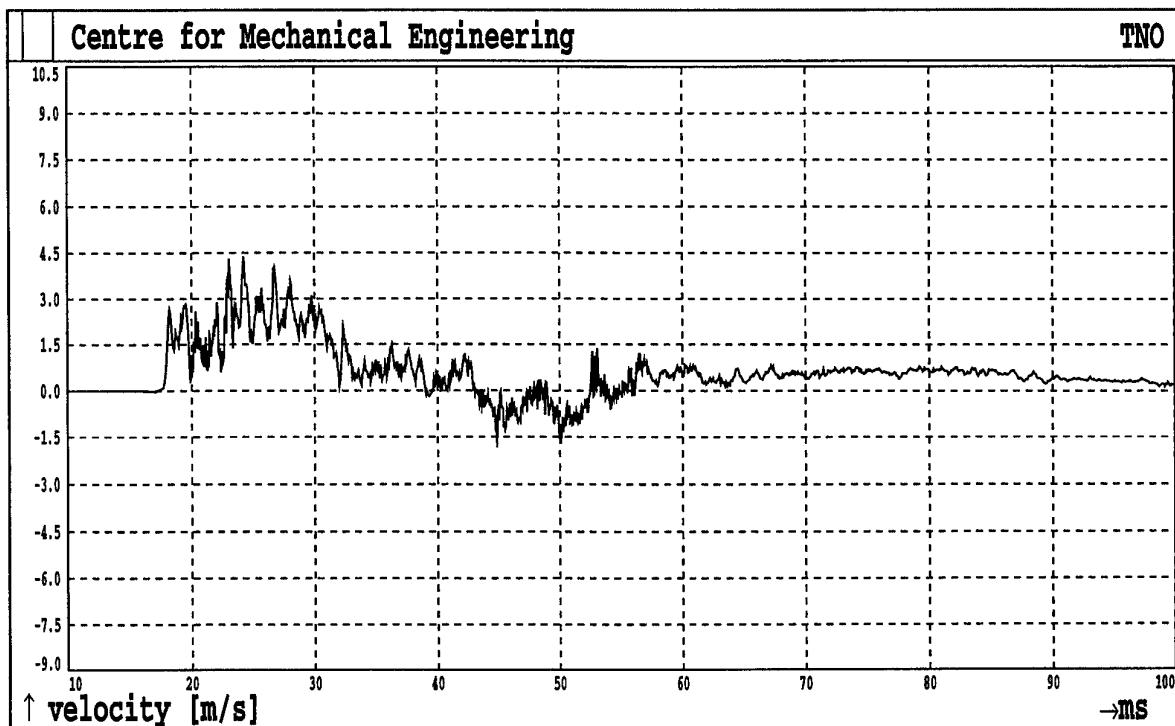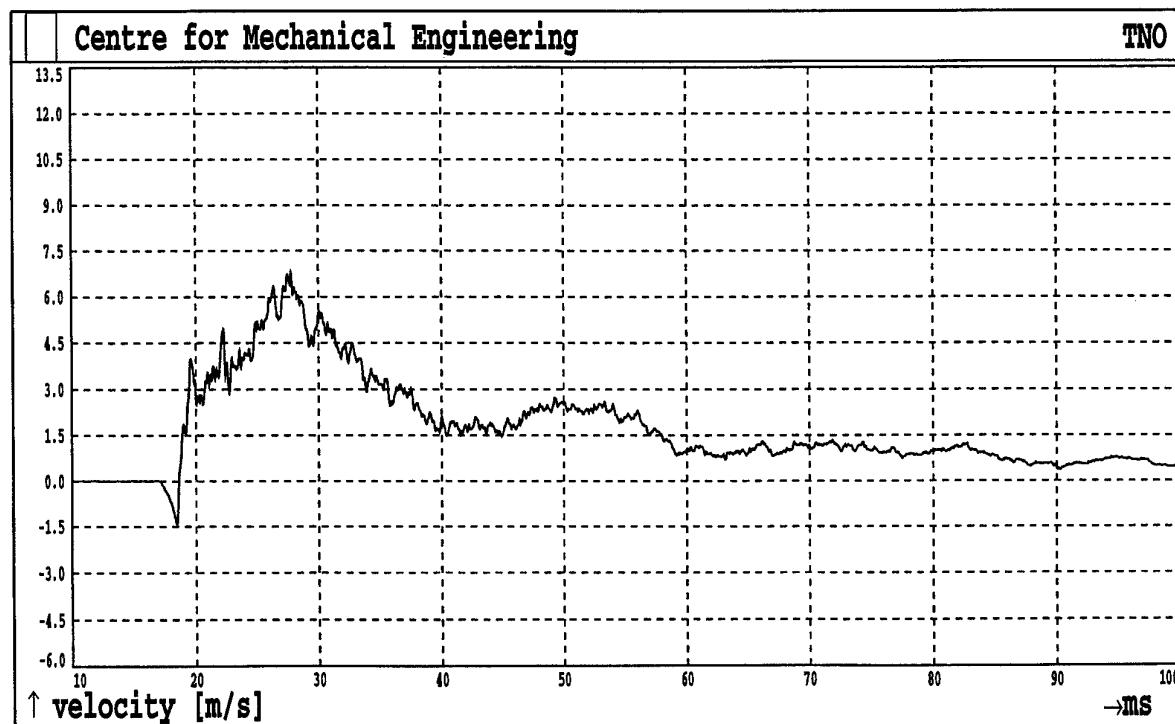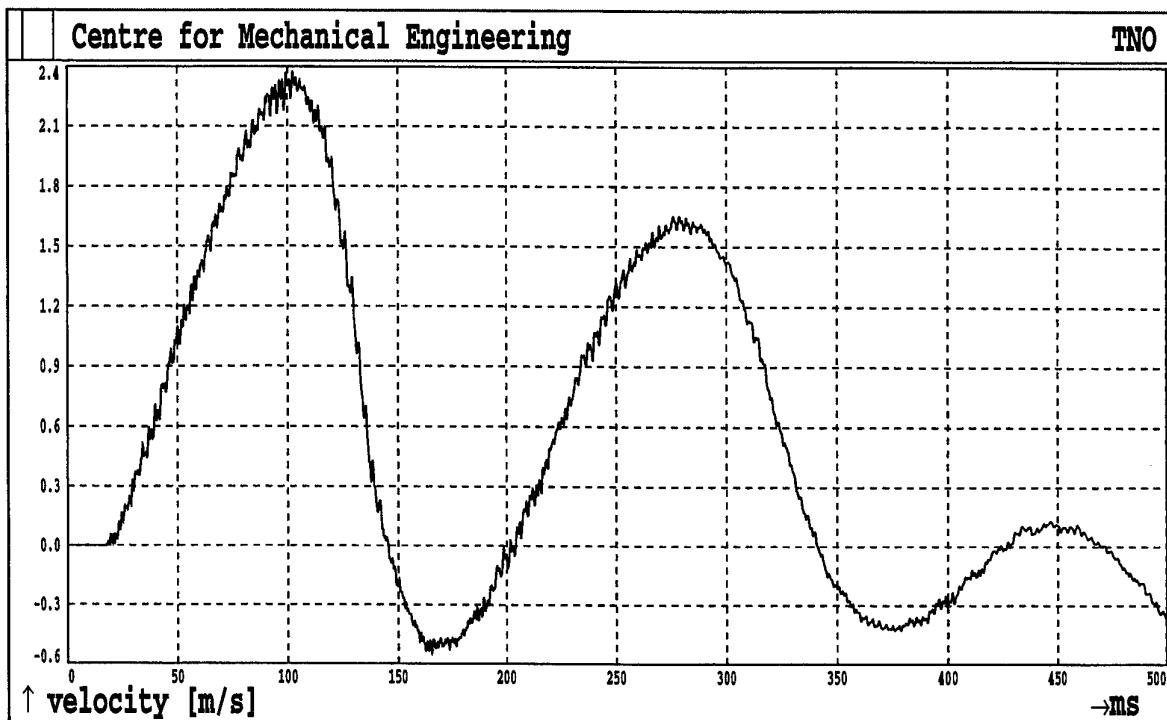
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Centre for Mechanical Engineering   **TNO**

↑ velocity [m/s]   →ms

Fig.86. Shot 4   Sensor A14

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↑ velocity [m/s]   →ms

Fig.87. Shot 4   Sensor A16

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Centre for Mechanical Engineering   **TNO**

↑ velocity [m/s]   →ms

Fig.88. Shot 4   Sensor A17

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↑ velocity [m/s]   →ms

Fig.89. Shot 4   Sensor A18

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Fig.90. Shot 4   Sensor A19

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Fig.91. Shot 4   Sensor A20

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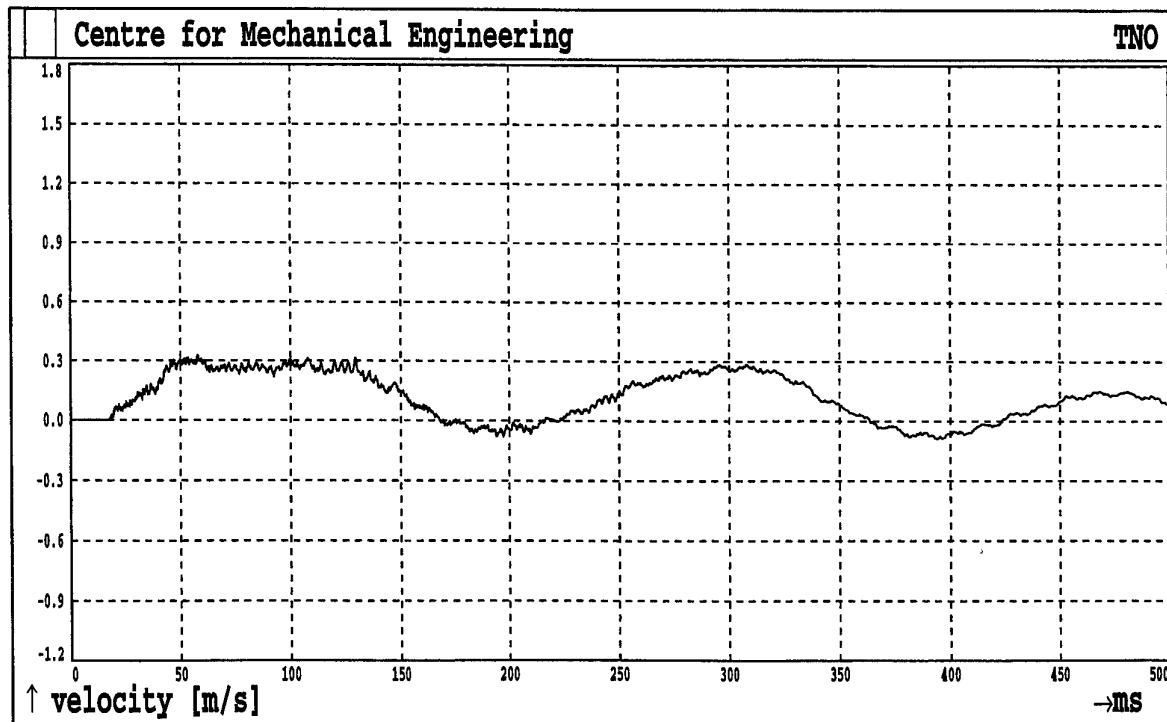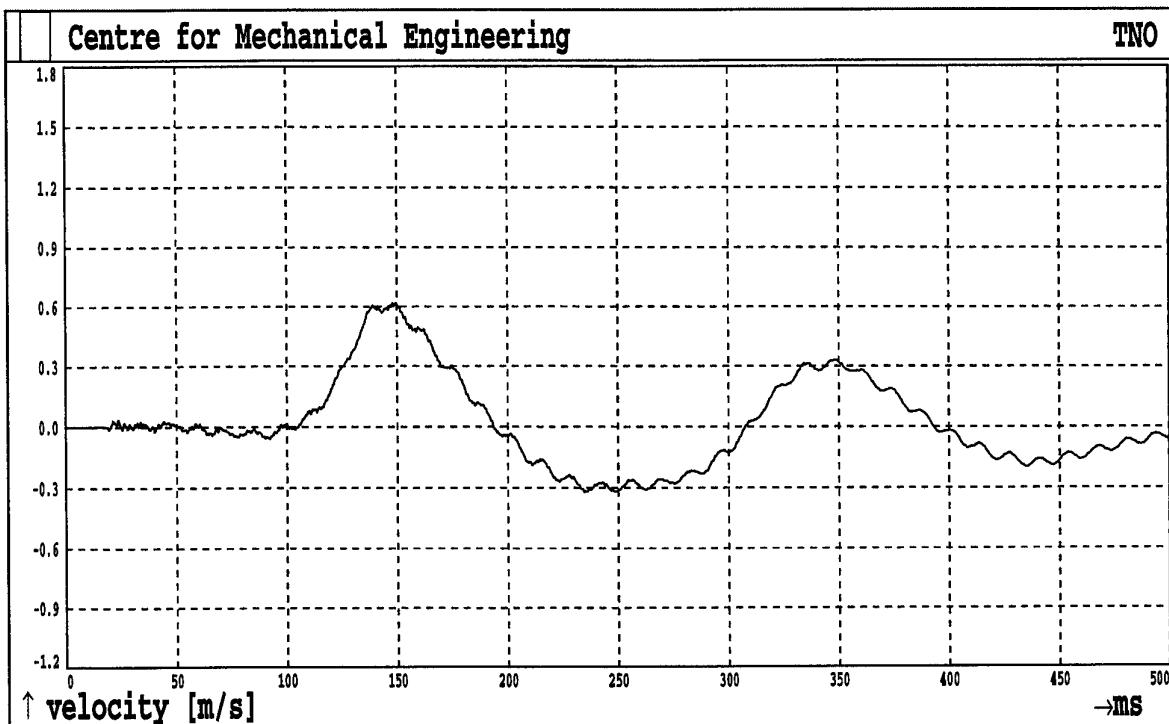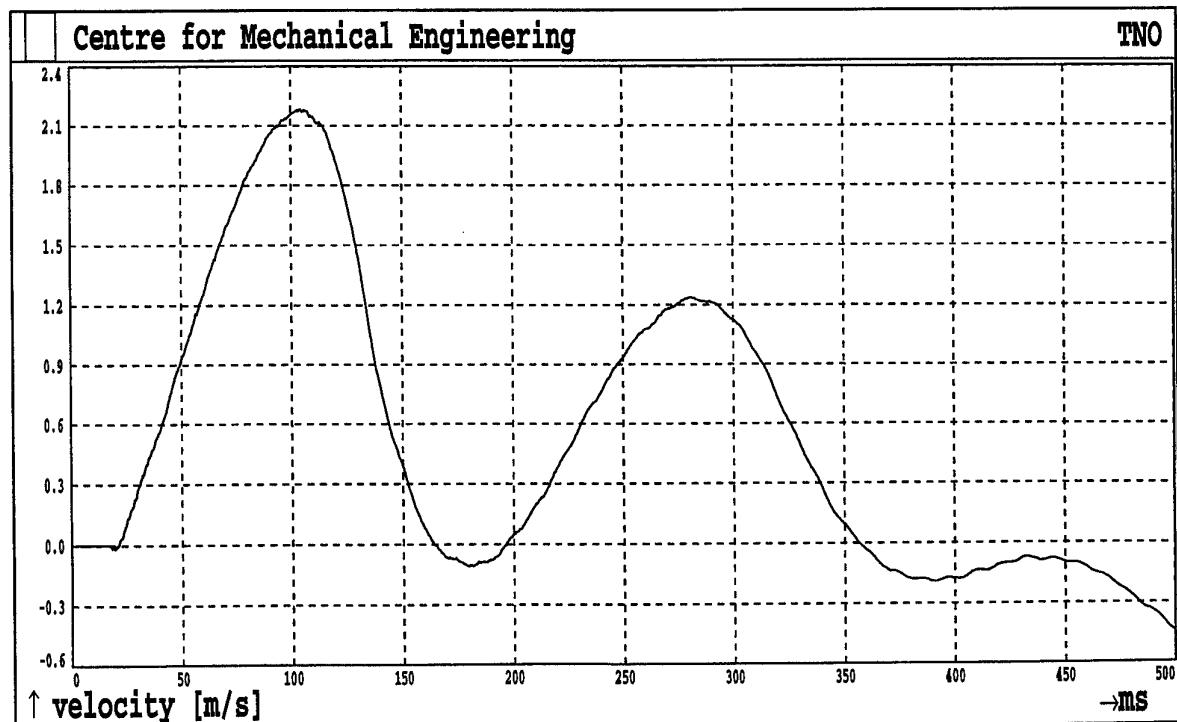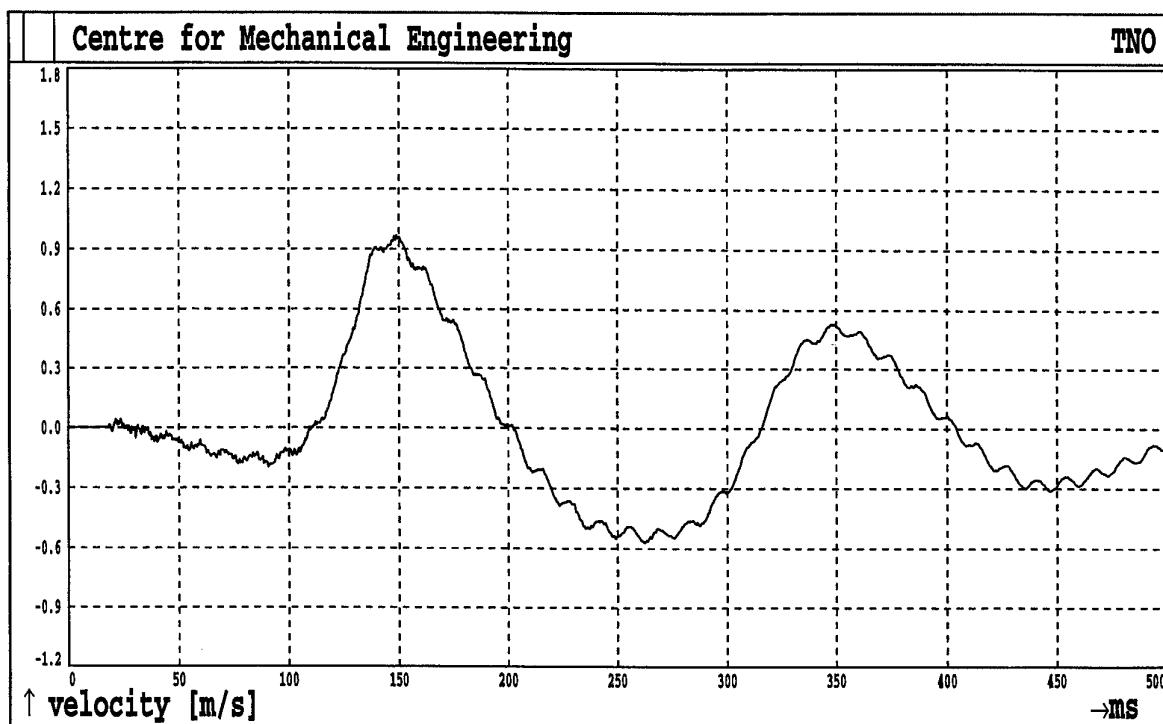
Fig.92. Shot 4 Sensor A21

Fig.93. Shot 4 Sensor A22
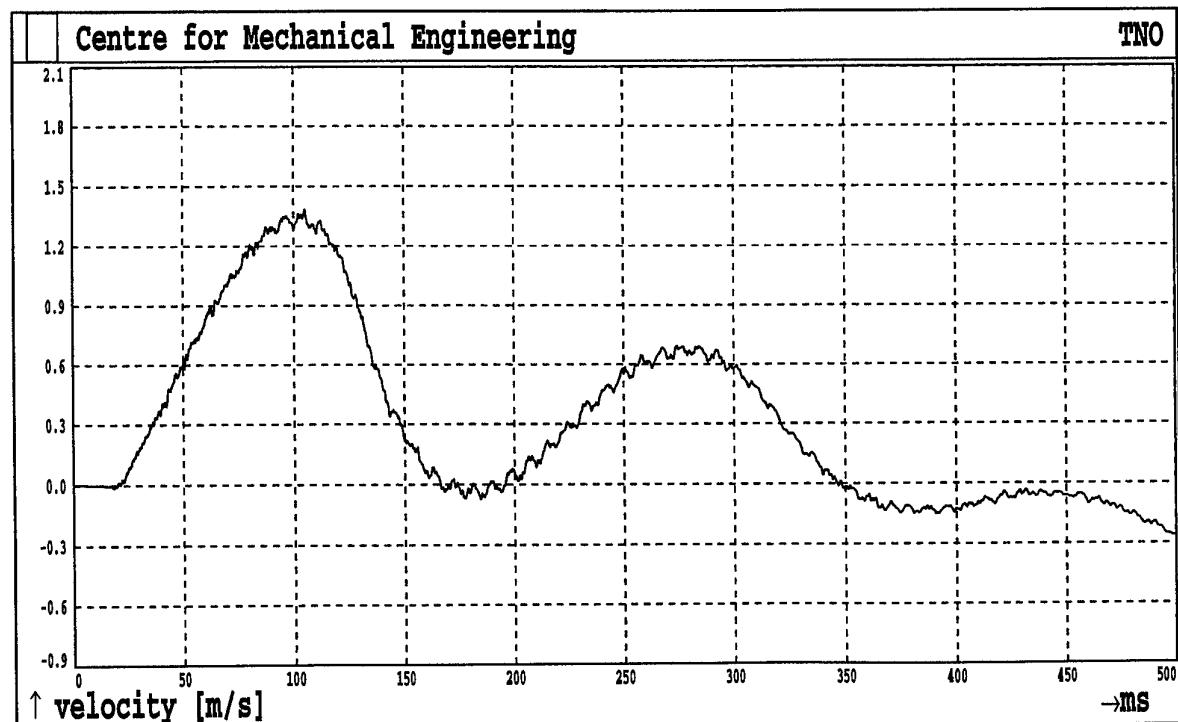
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Fig.94. Shot 4   Sensor A23

Fig.95. Shot 4   Sensor A24
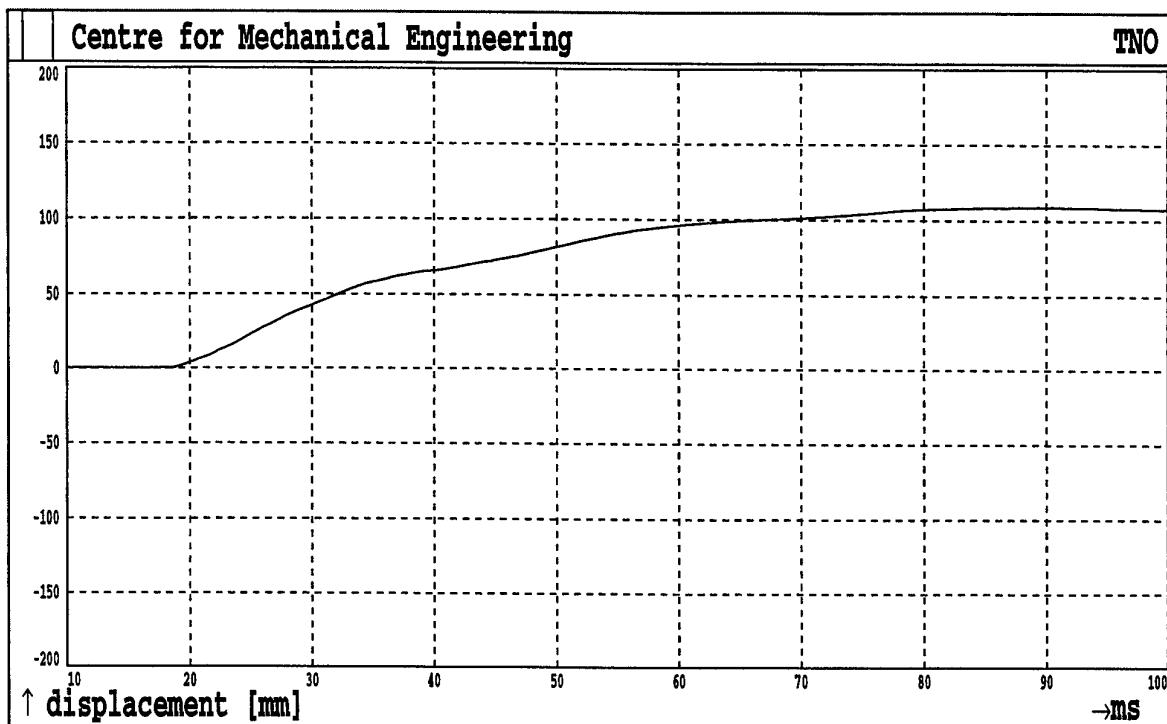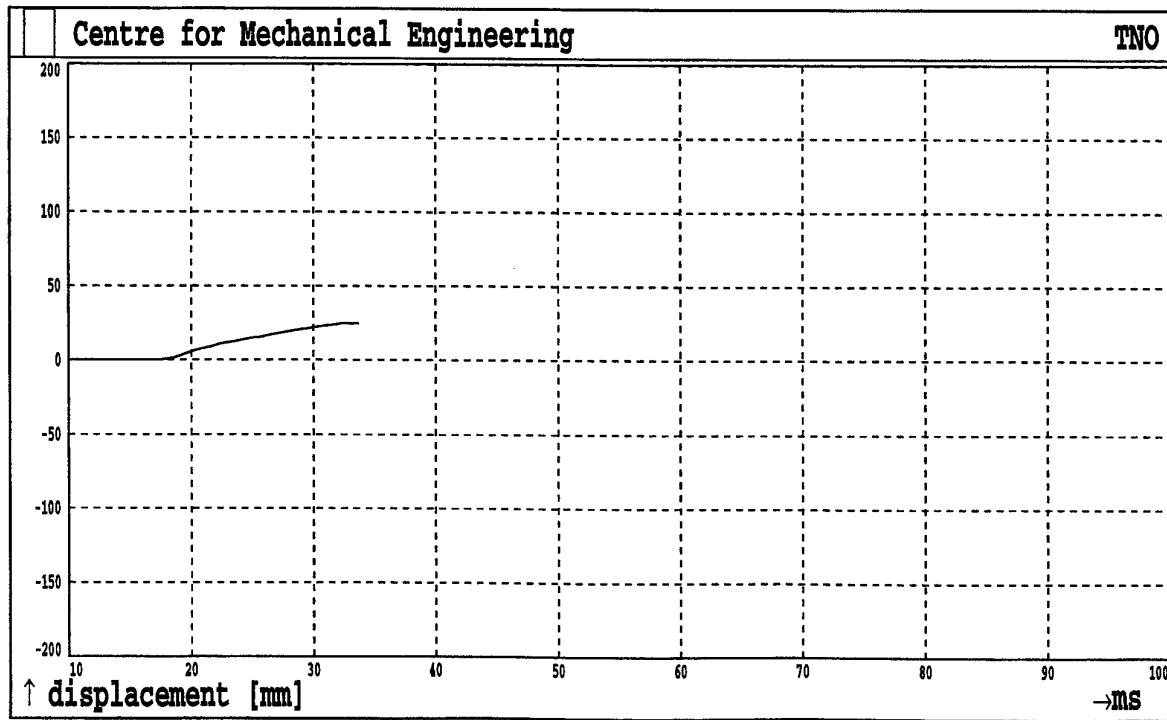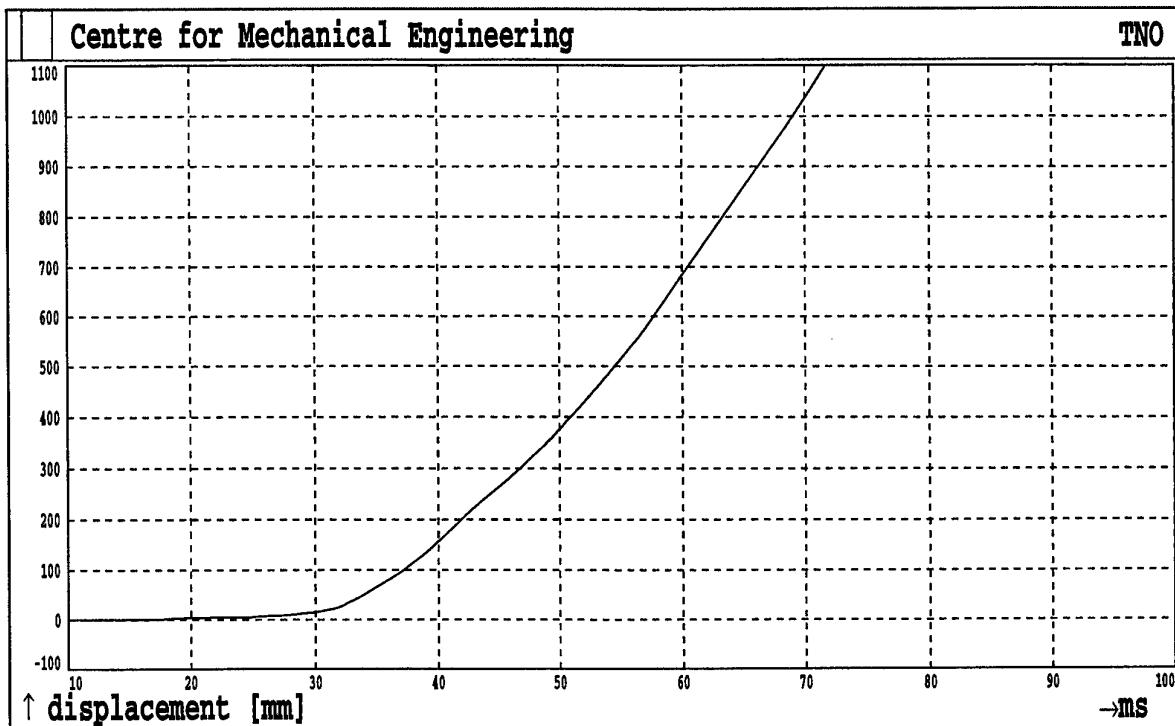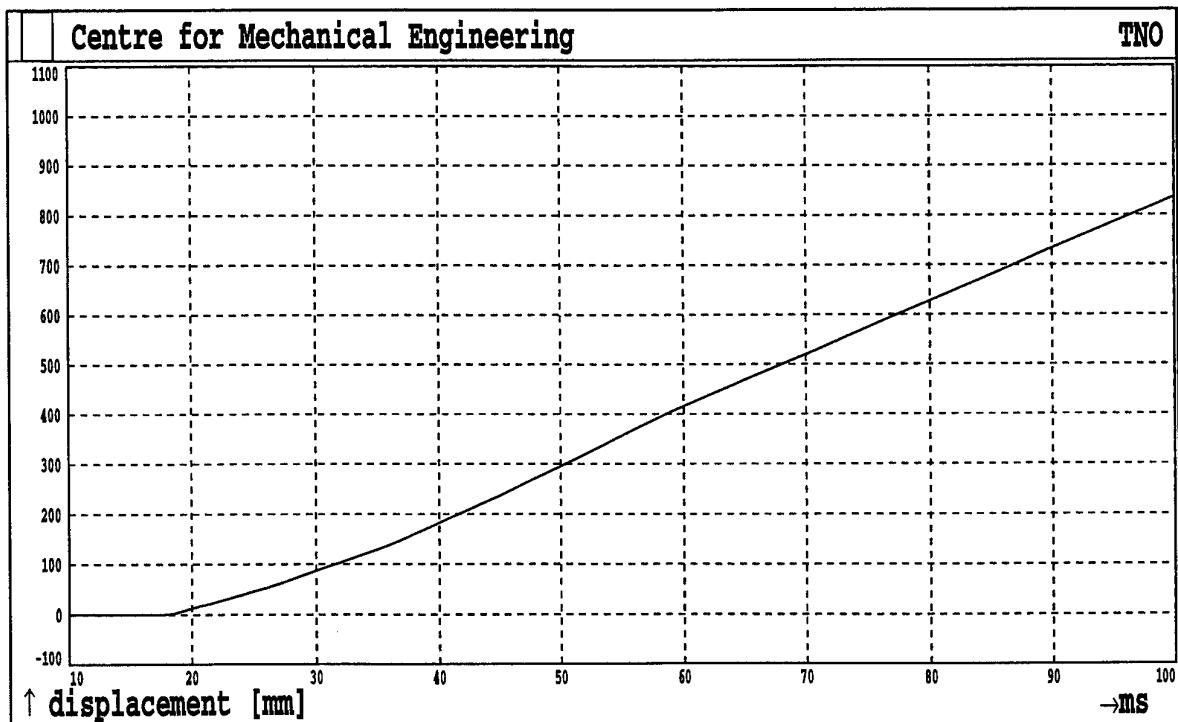
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Fig.96. Shot 4   Sensor A2

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Fig.97. Shot 4   Sensor A3

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↑ displacement [mm]   →ms

Fig.98. Shot 4 Sensor A4

Centre for Mechanical Engineering   **TNO**

↑ displacement [mm]   →ms

Fig.99. Shot 4 Sensor A5

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Fig.100. Shot 4　Sensor A6

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Fig.101. Shot 4　Sensor A8

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Fig.102. Shot 4　Sensor A9

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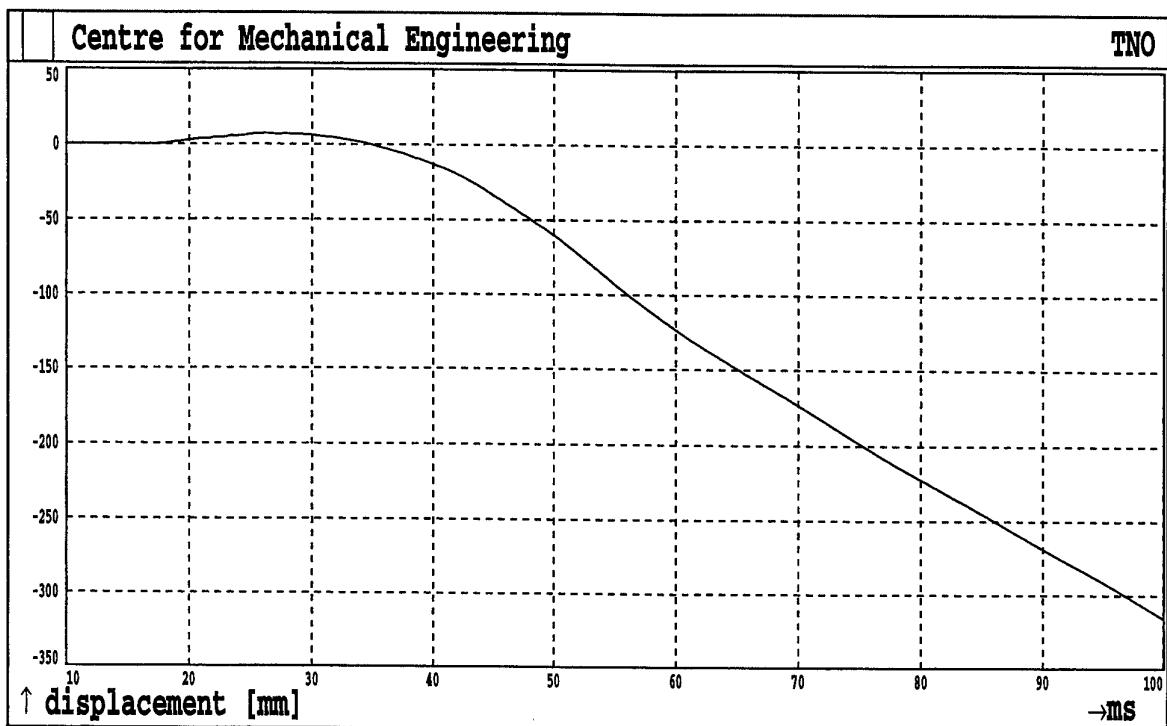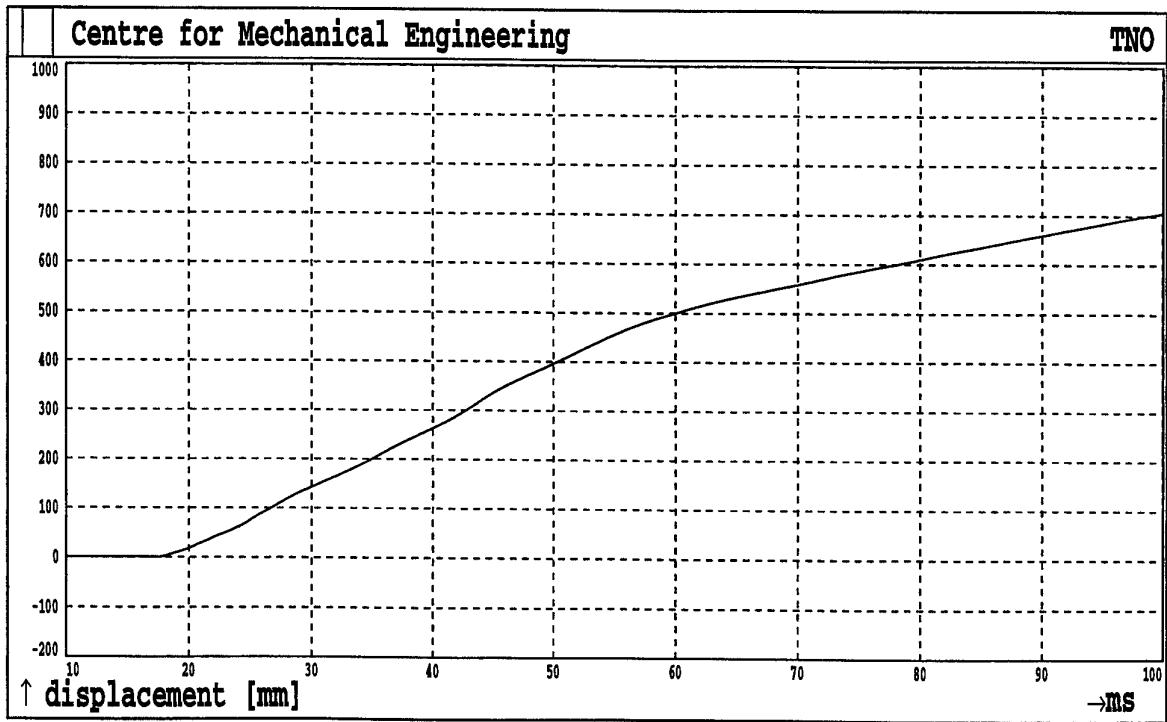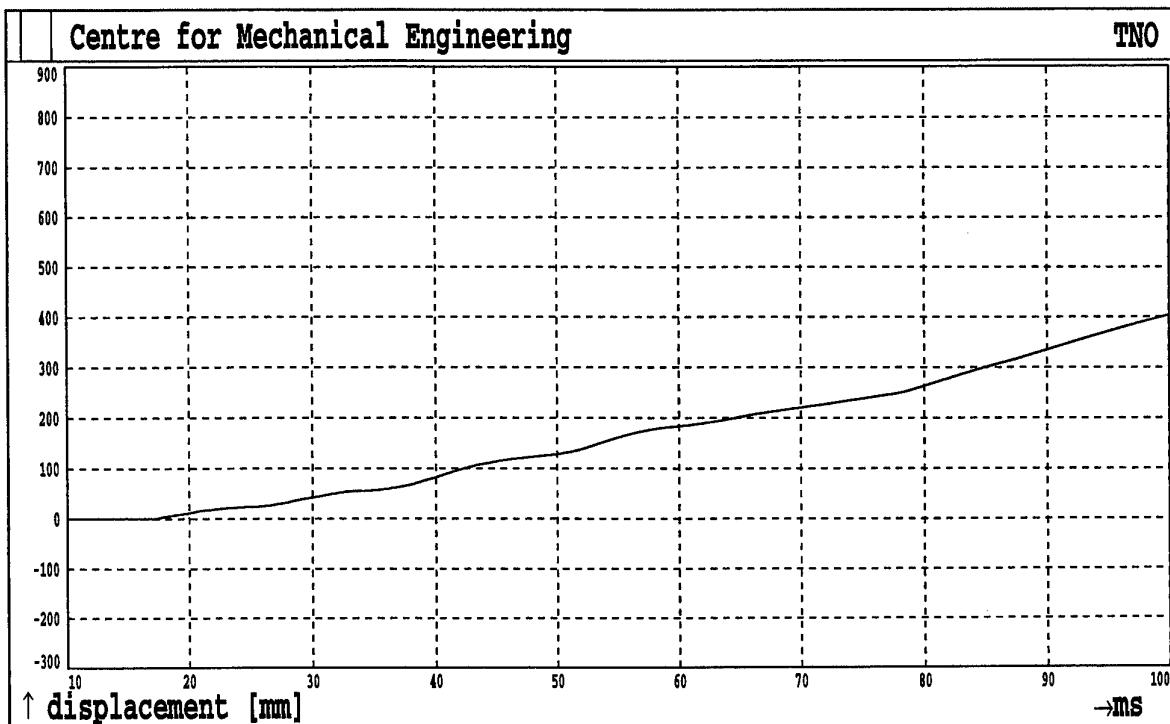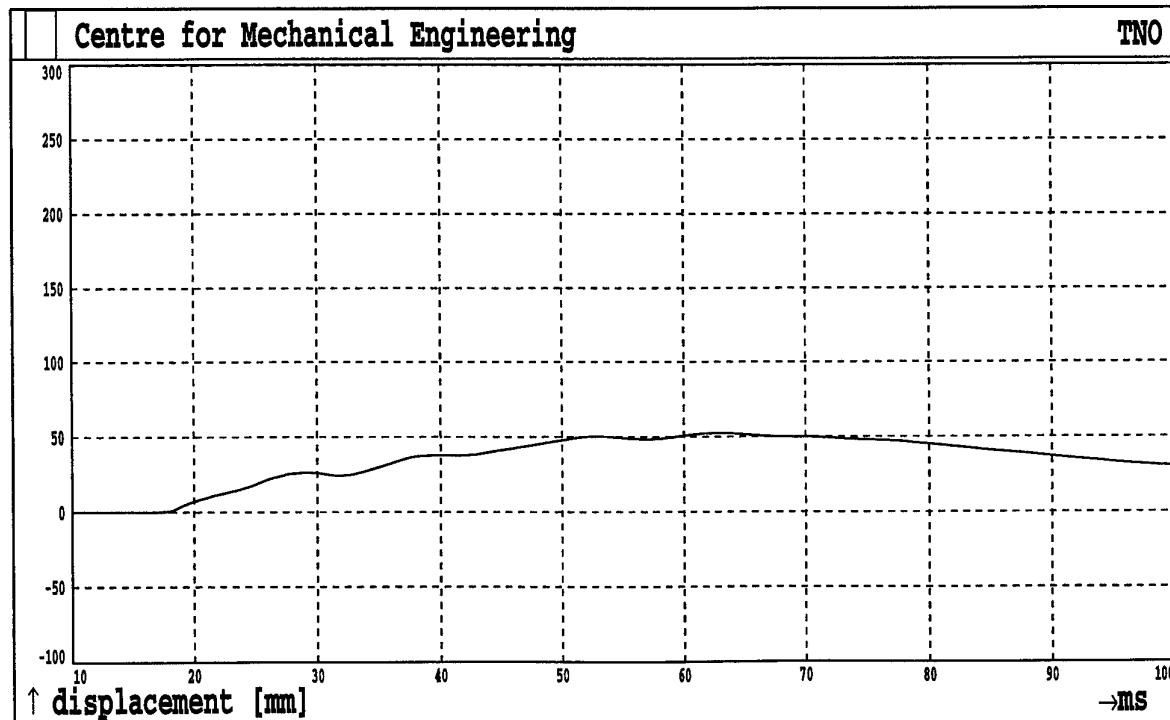
Fig.103. Shot 4　Sensor A10
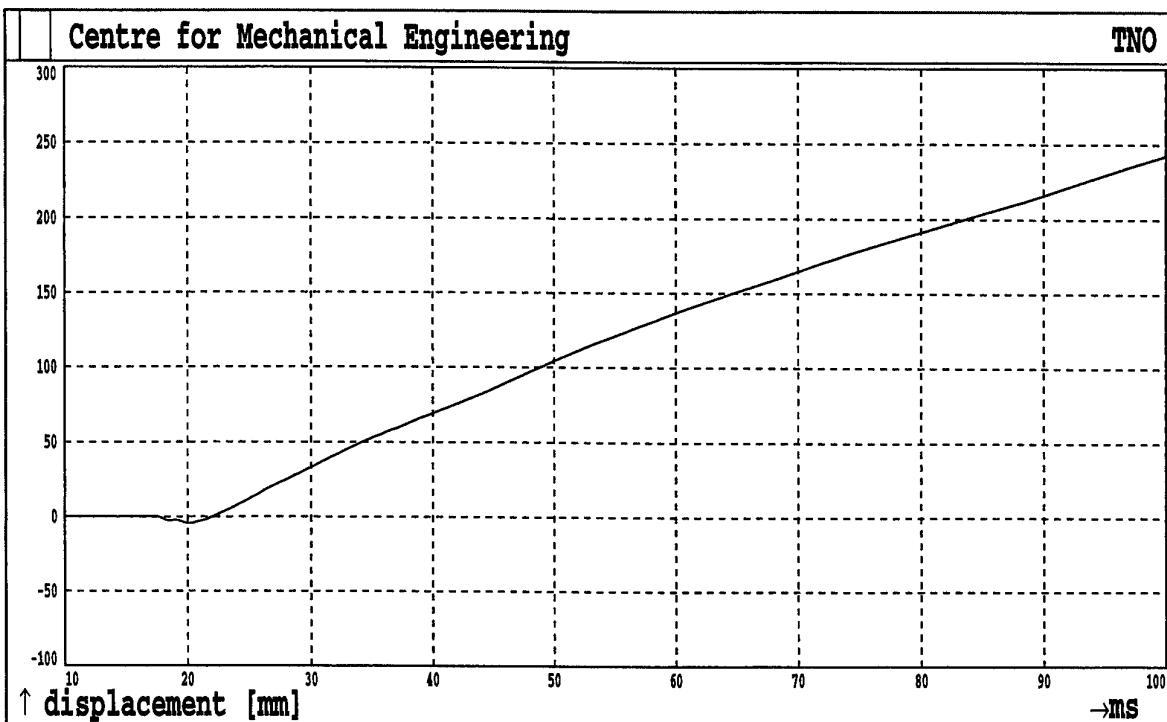
Fig.104. Shot 4 Sensor A11

Fig.105. Shot 4 Sensor A12

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↑ displacement [mm]   →ms

Fig.106. Shot 4 Sensor A13

Centre for Mechanical Engineering   **TNO**

↑ displacement [mm]   →ms
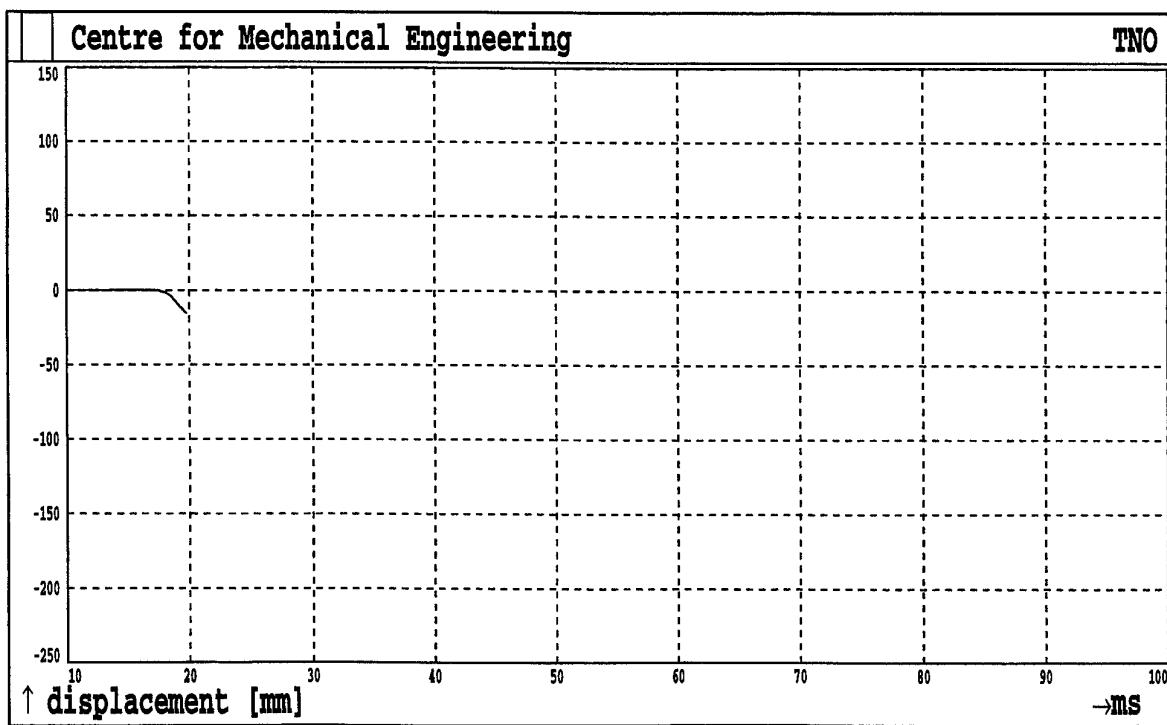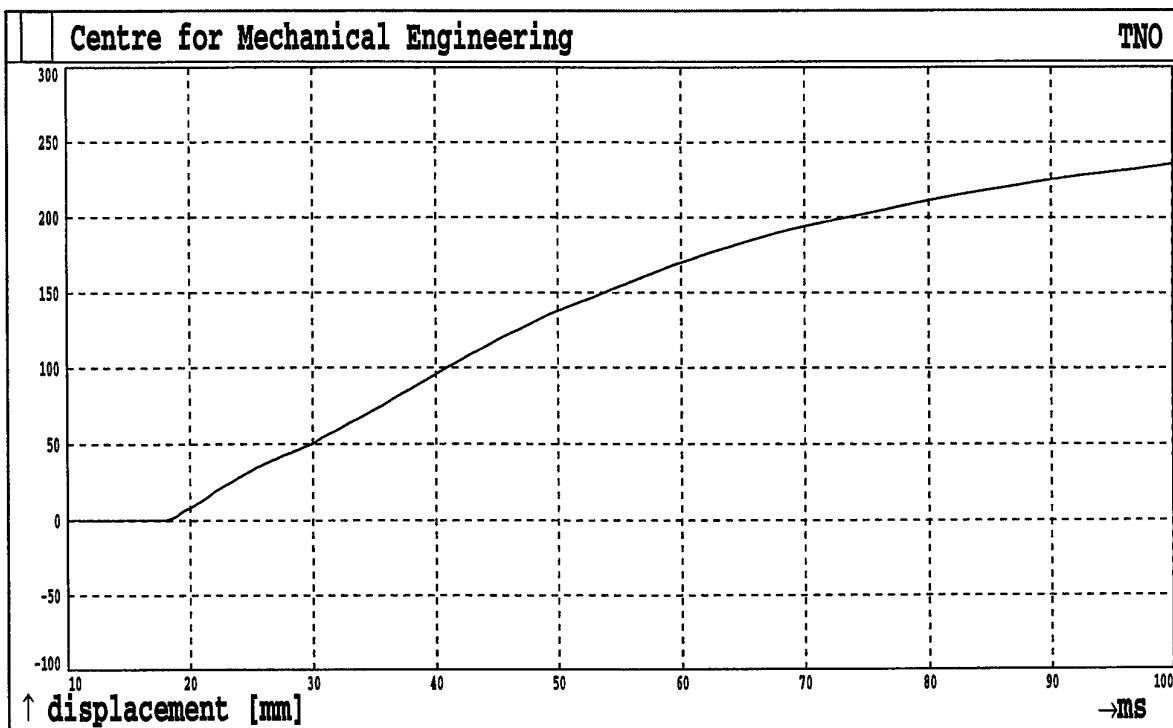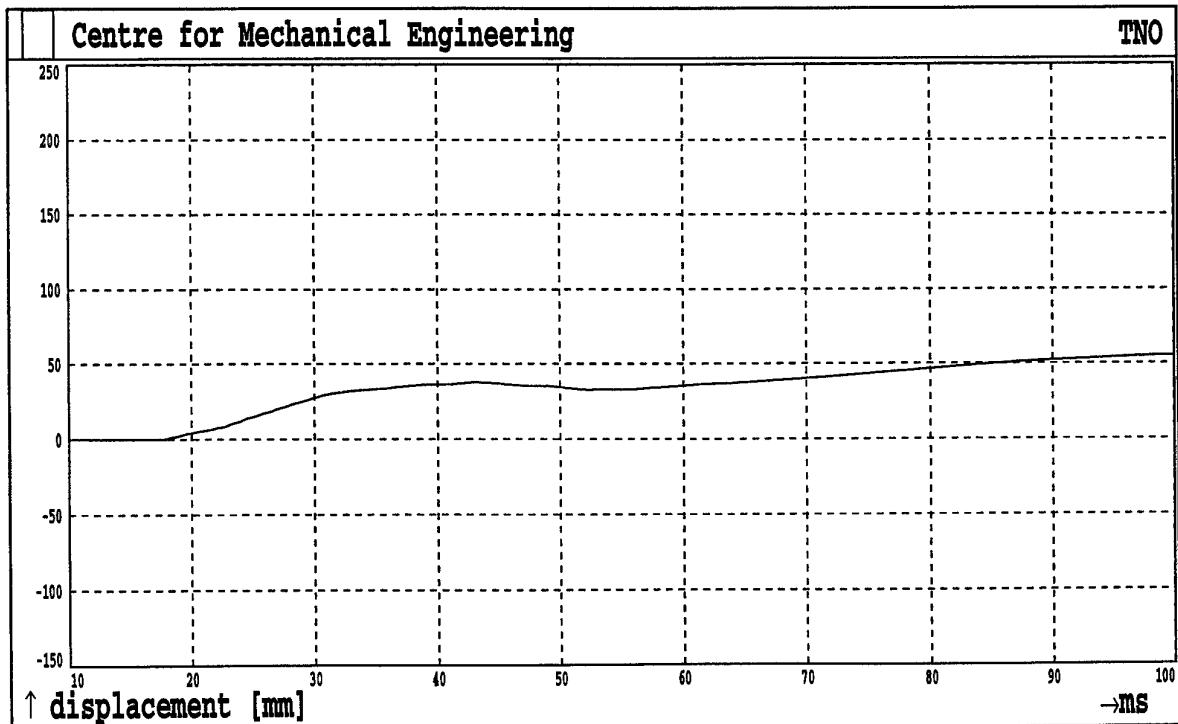
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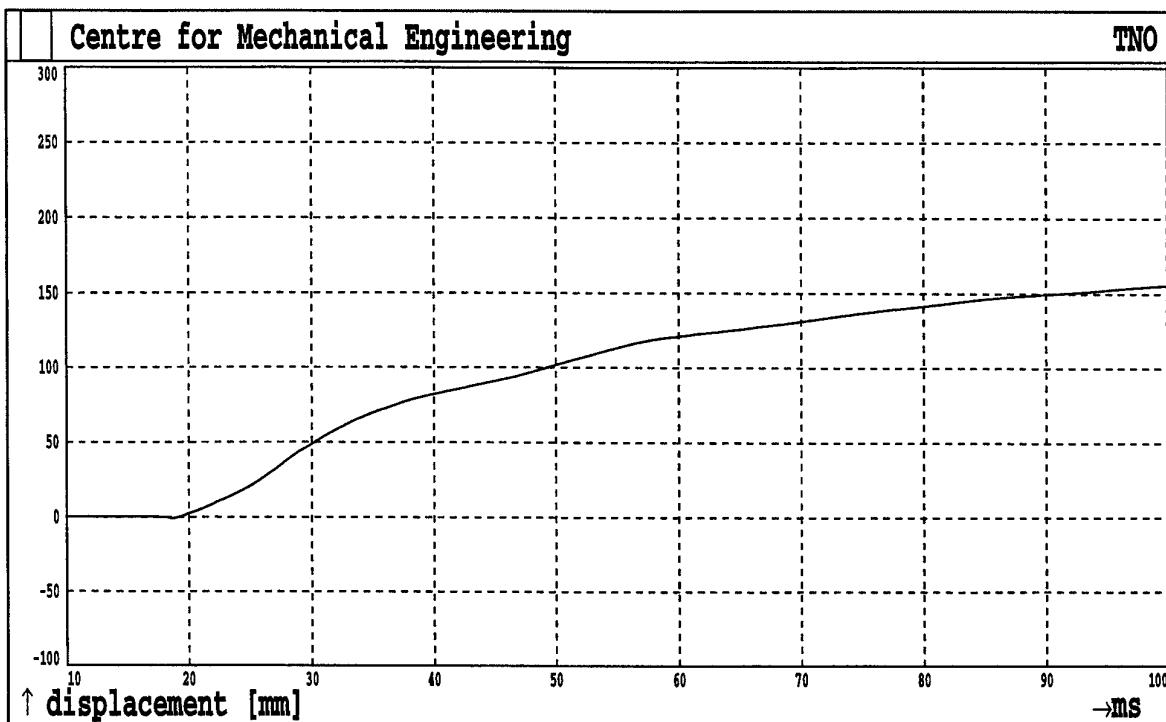
Fig.108. Shot 4 Sensor A16

Fig.109. Shot 4 Sensor A17

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Fig.110. Shot 4 Sensor A18

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Fig.111. Shot 4 Sensor A19

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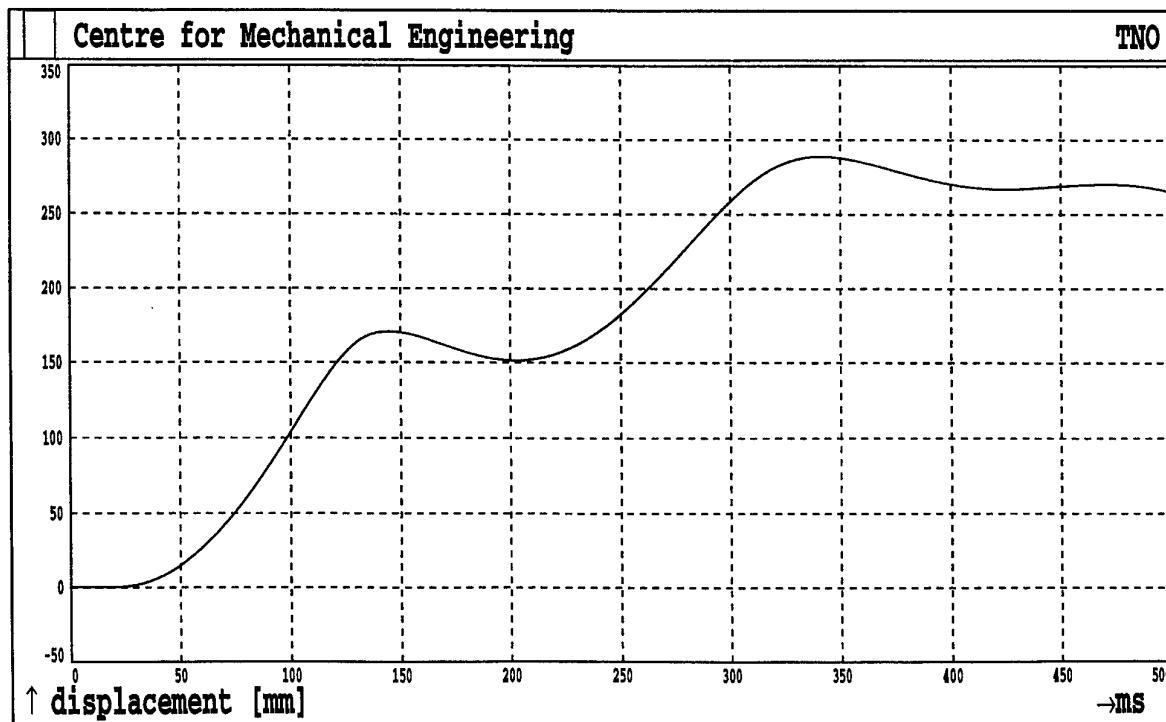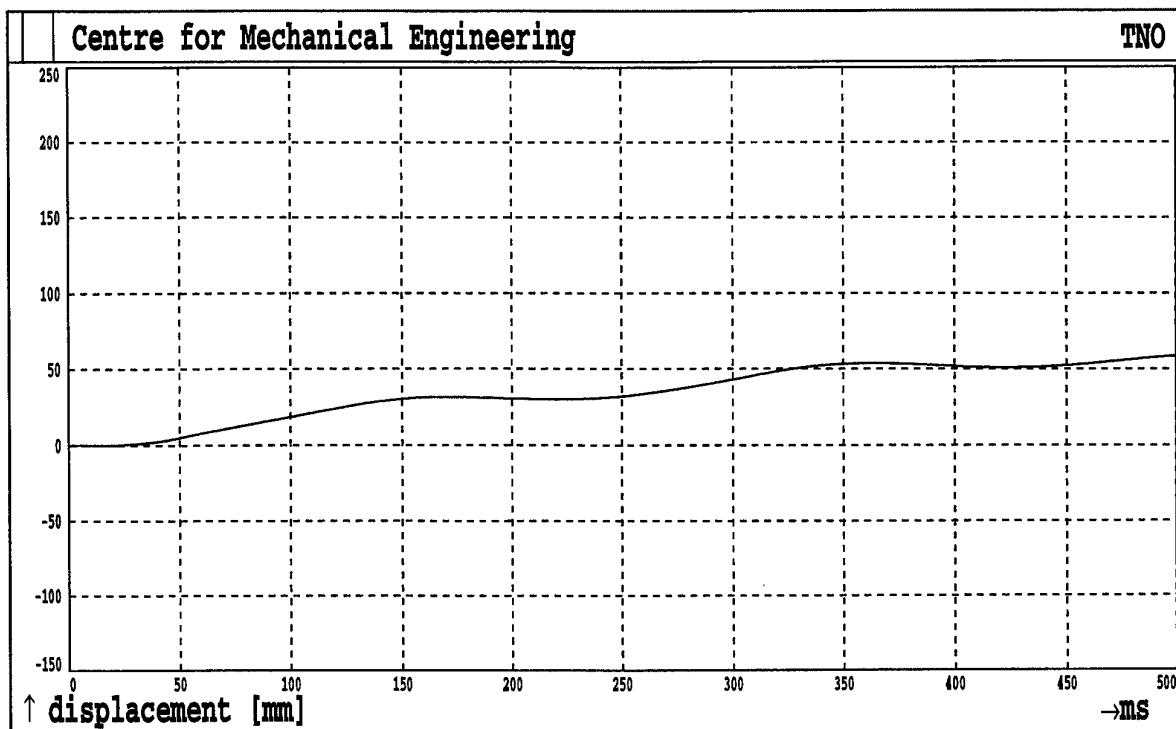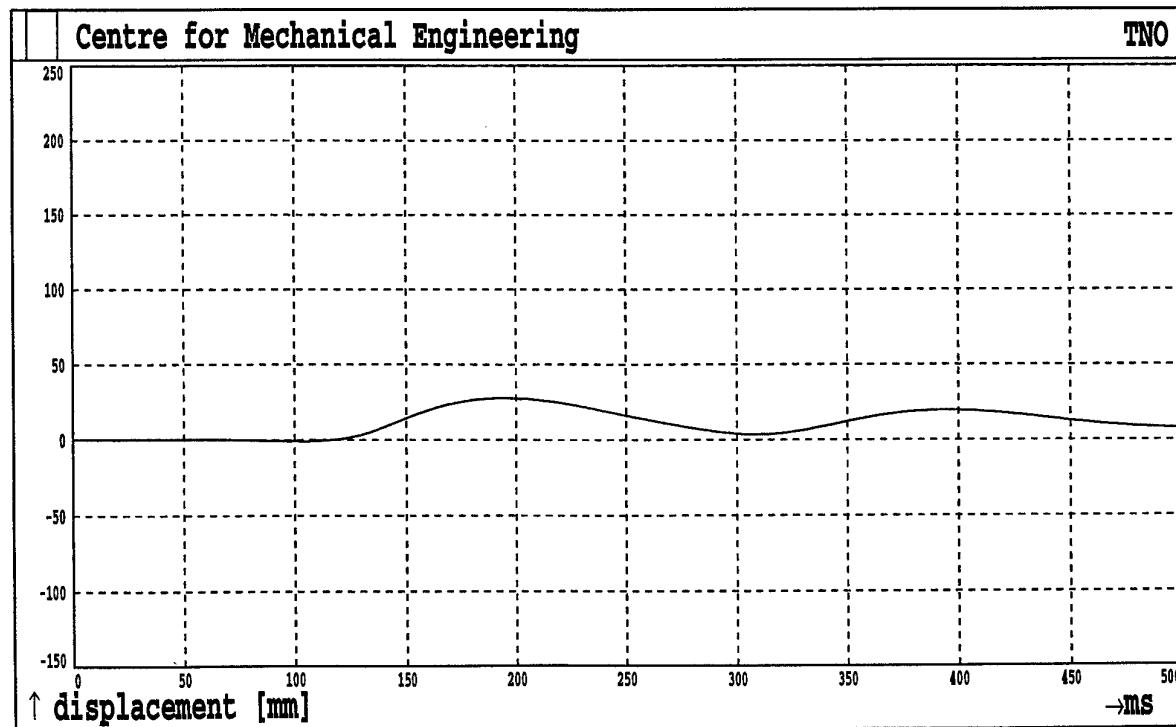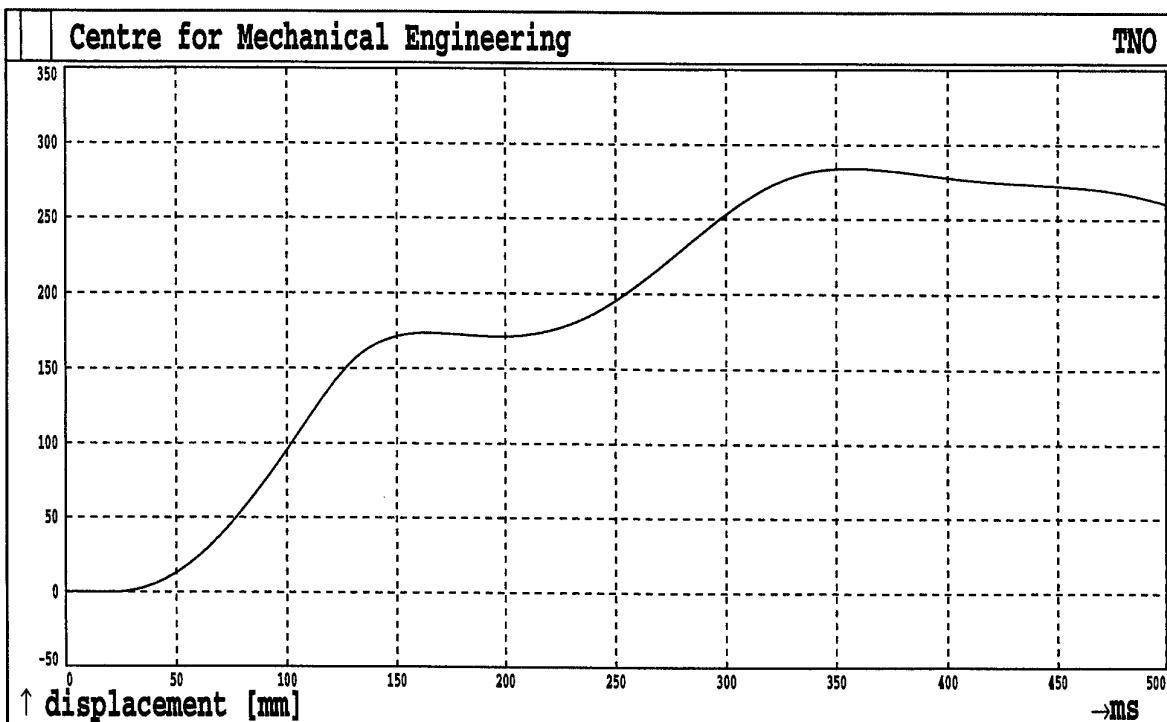
Fig.112. Shot 4 Sensor A20

Fig.113. Shot 4 Sensor A21
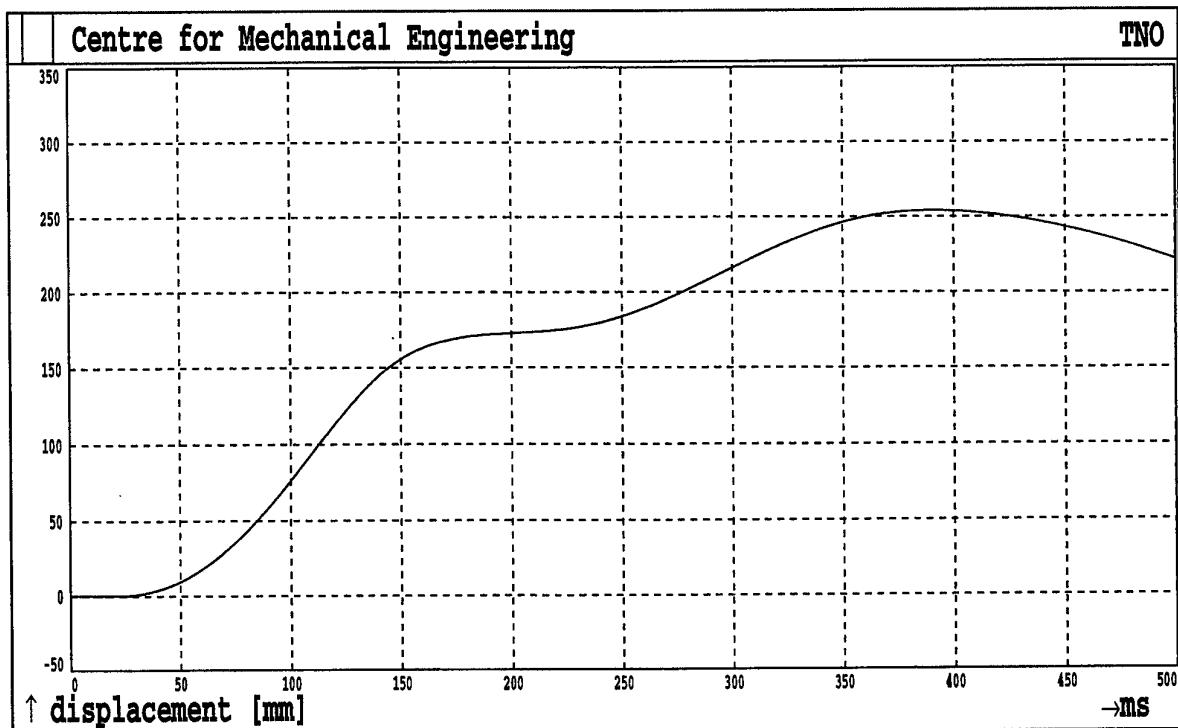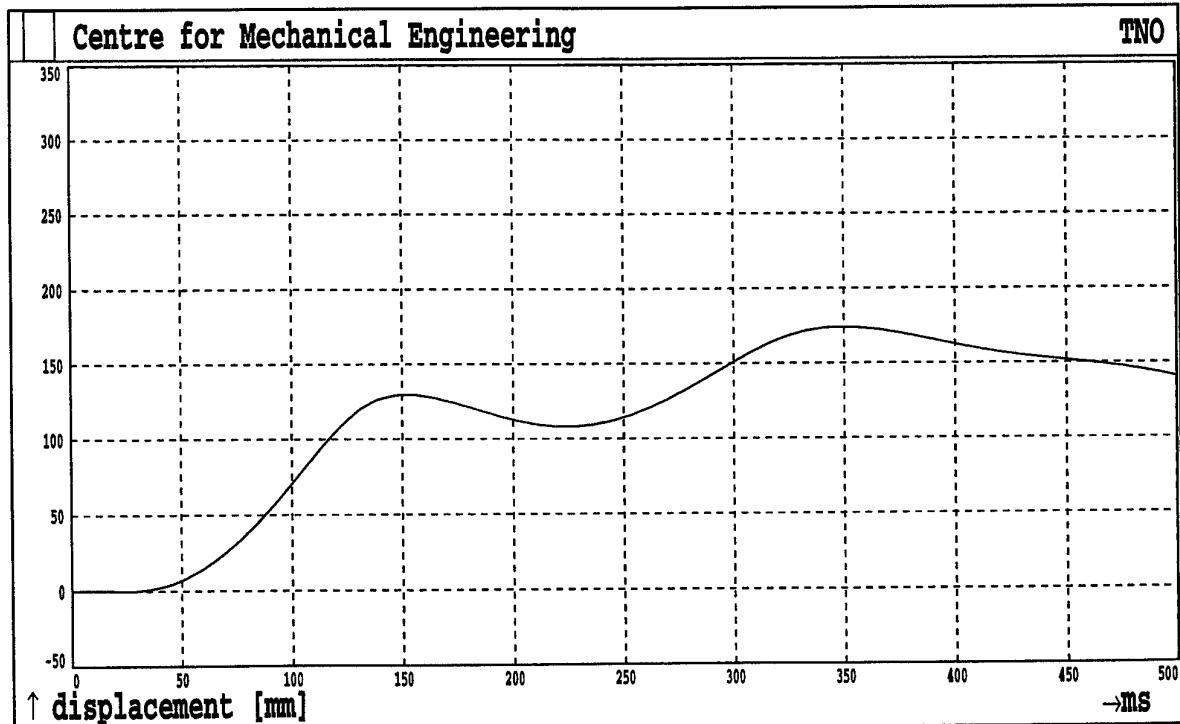
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Fig.114. Shot 4 Sensor A22

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Fig.115. Shot 4 Sensor A23

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Fig.116. Shot 4   Sensor A24

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↑ pseudo velocity [m/s]   →kHz

Fig.117. Shot 4 MAXIMAX Sensor A2

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↑ pseudo velocity [m/s]   →kHz
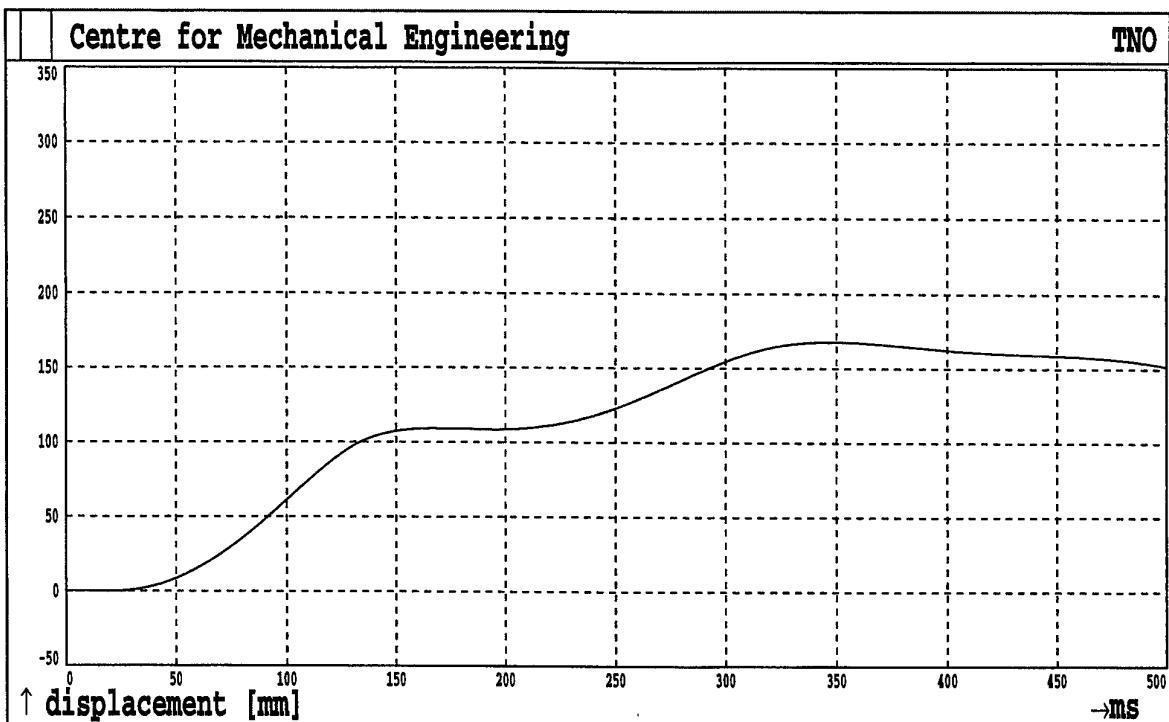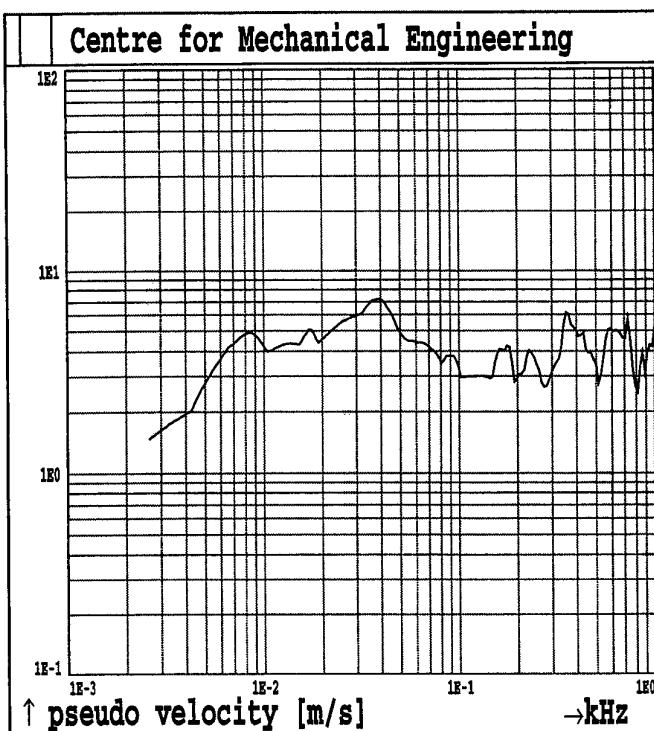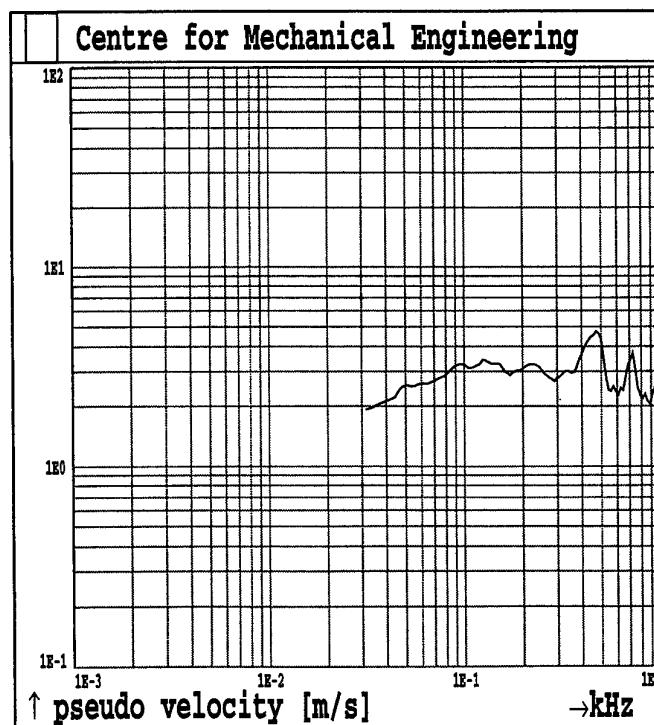
Fig.118. Shot 4 Sensor A3; SRS calculated
only over the first 15 ms signal
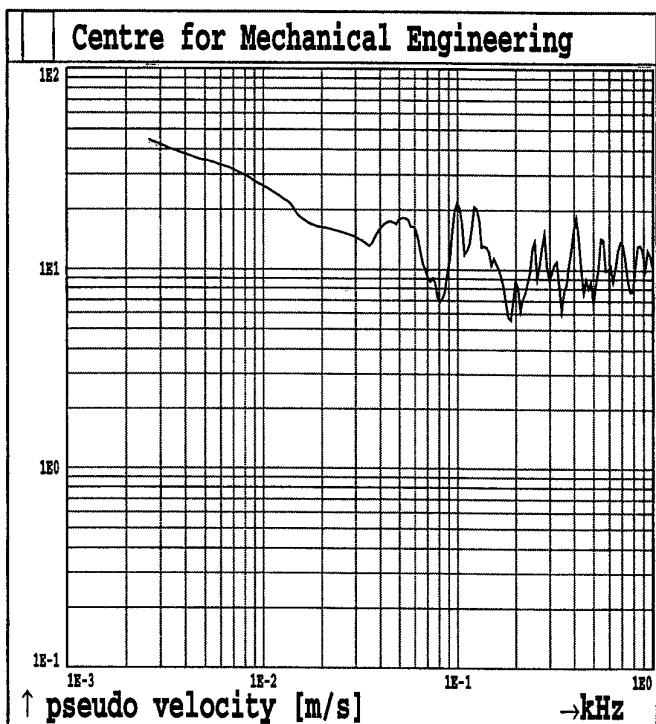
Fig.119. Shot 4 MAXIMAX Sensor A4
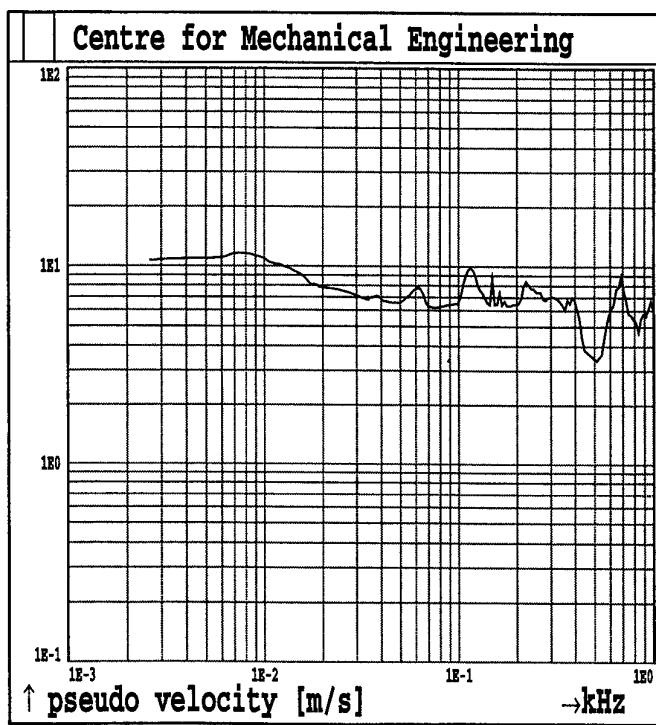
Fig.120. Shot 4 MAXIMAX Sensor A5

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↑ pseudo velocity [m/s]   →kHz
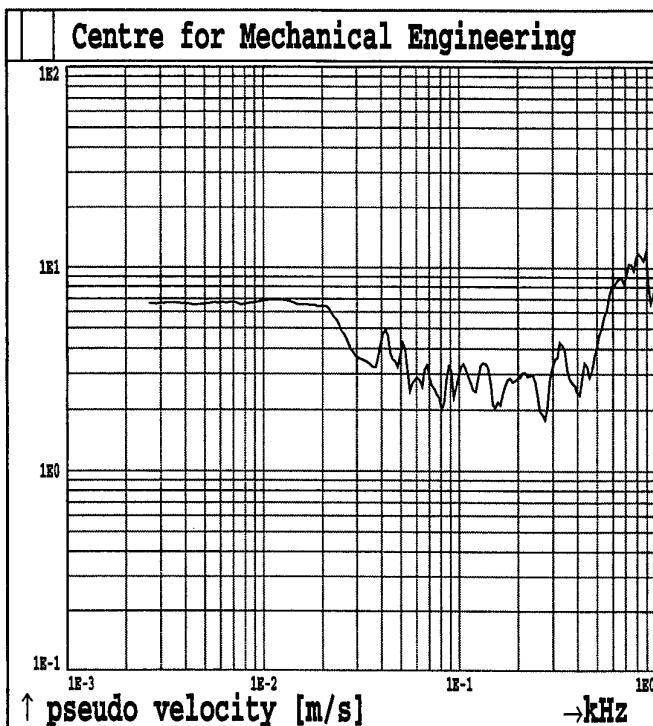
Fig.121. Shot 4 MAXIMAX Sensor A6

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↑ pseudo velocity [m/s]   →kHz
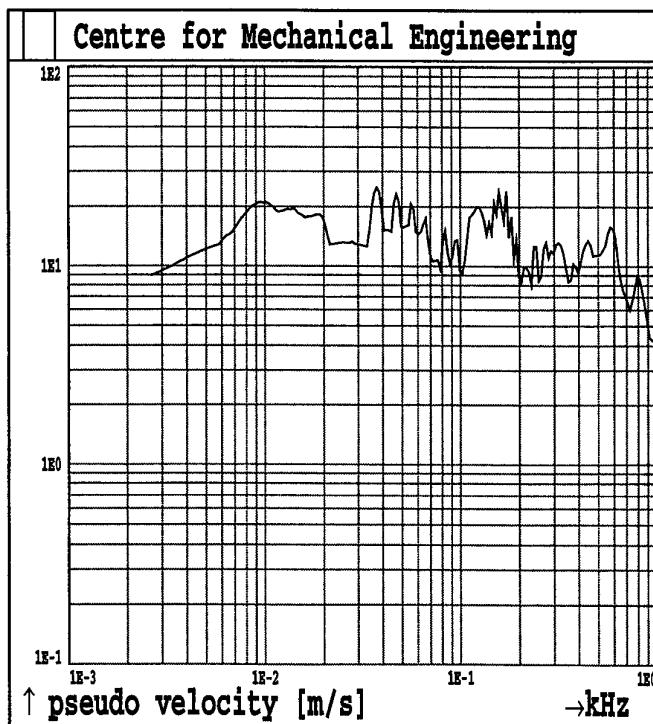
Fig.122. Shot 4 MAXIMAX Sensor A8

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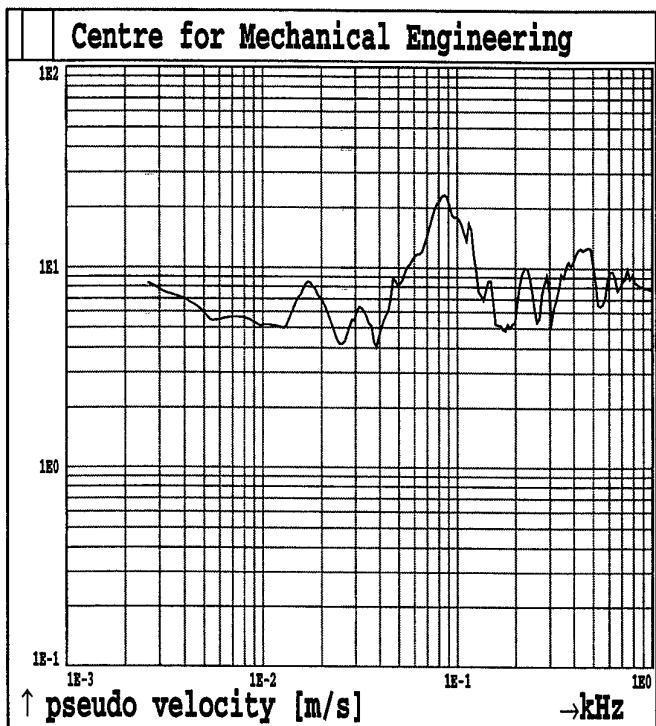
Fig.123. Shot 4 MAXIMAX Sensor A9
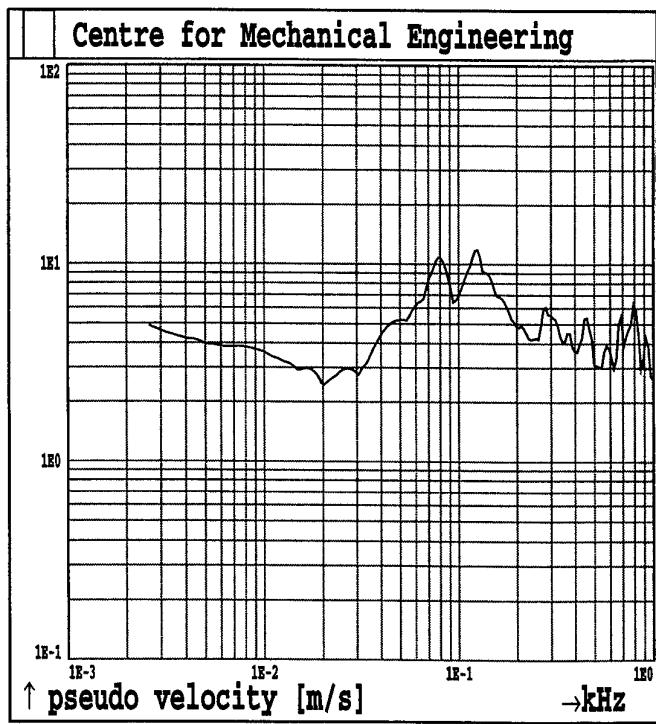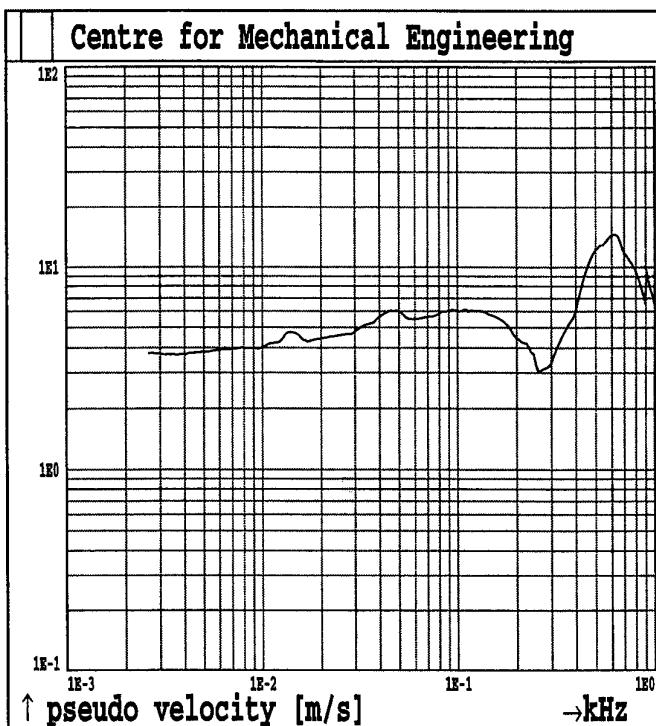
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Fig.124. Shot 4 MAXIMAX Sensor A10

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Fig.125. Shot 4 MAXIMAX Sensor A11

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Fig.126. Shot 4 MAXIMAX Sensor A13

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↑ pseudo velocity [m/s]   →kHz

Fig.127. Shot 4   MAXIMAX   Sensor A14

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↑ pseudo velocity [m/s]   →kHz
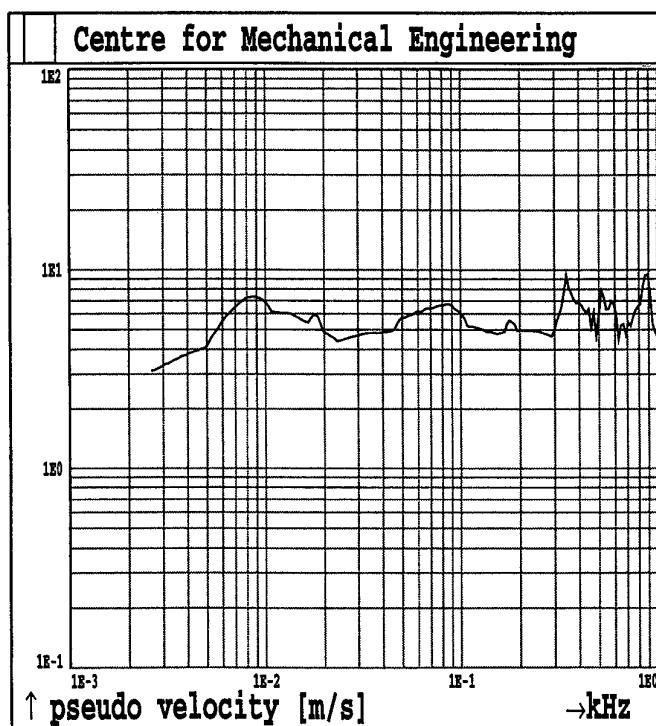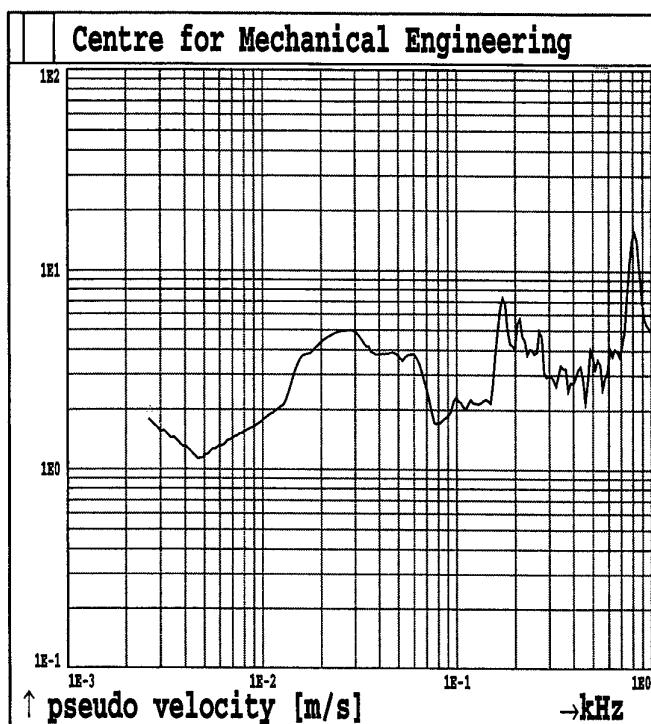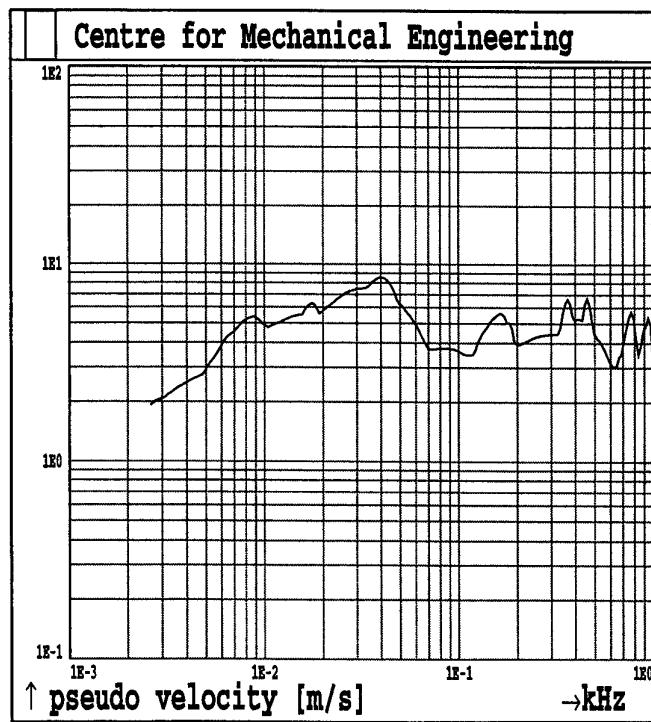
Fig.128. Shot 4   MAXIMAX   Sensor A16

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Fig.129. Shot 4 MAXIMAX Sensor A17

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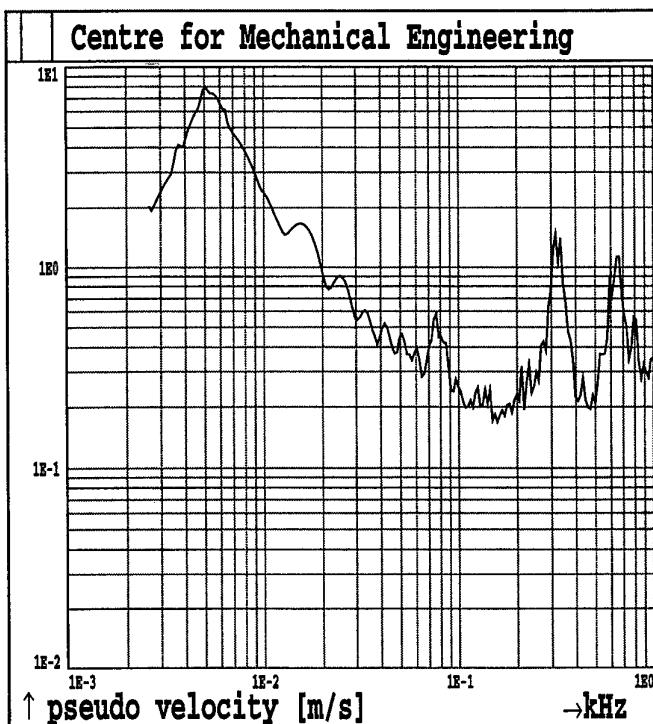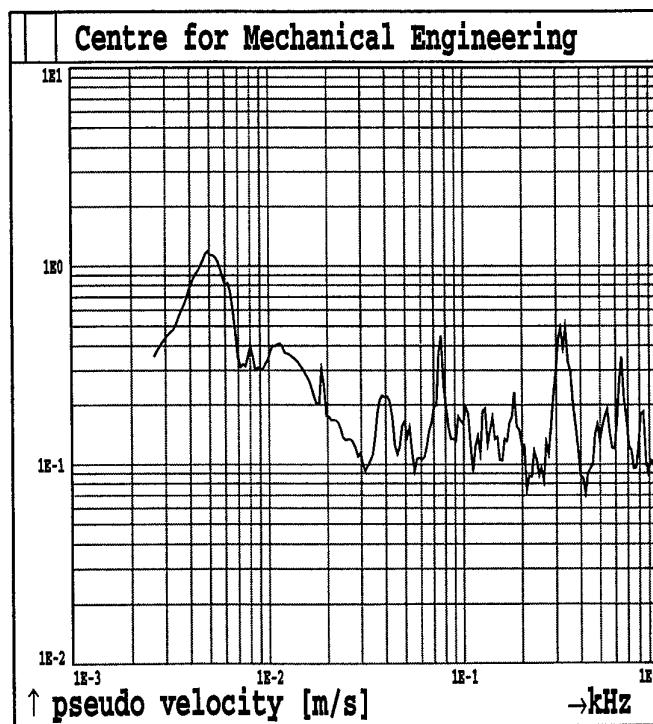
Fig.130. Shot 4 MAXIMAX Sensor A18
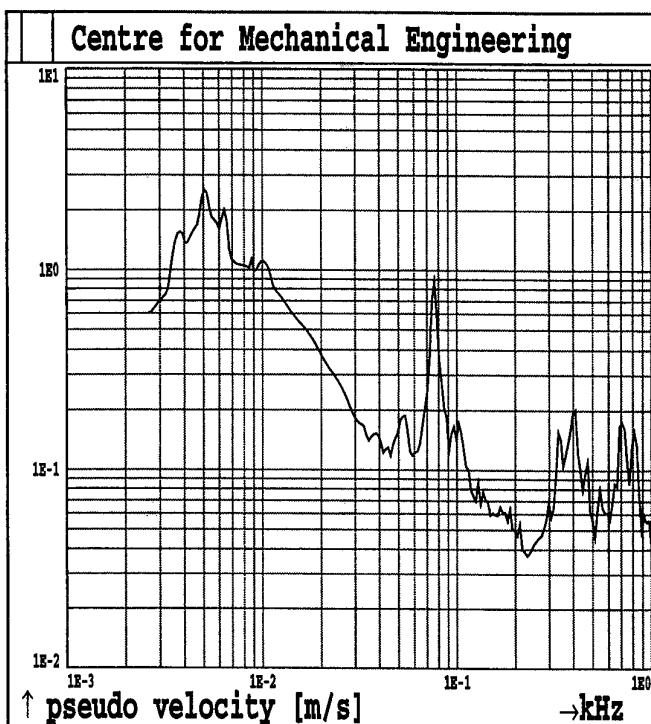
Fig.131. Shot 4 MAXIMAX Sensor A19
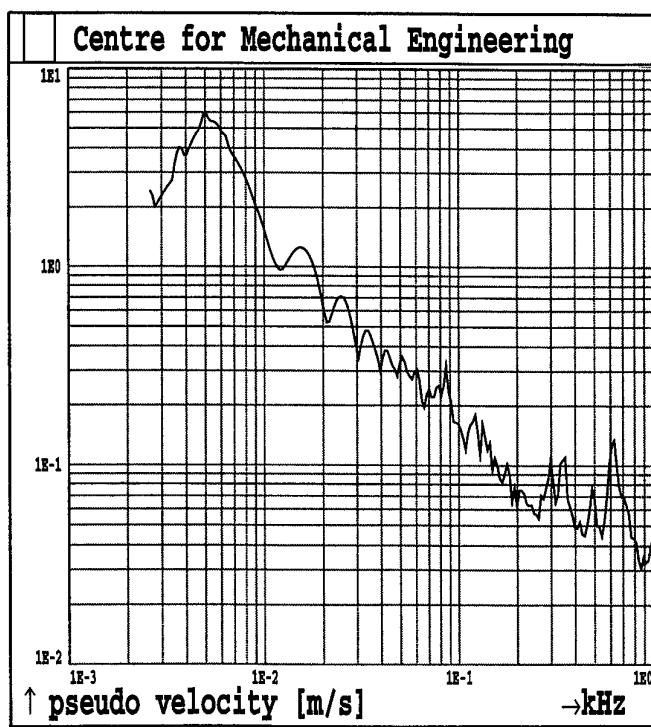
Fig.132. Shot 4 MAXIMAX Sensor A20

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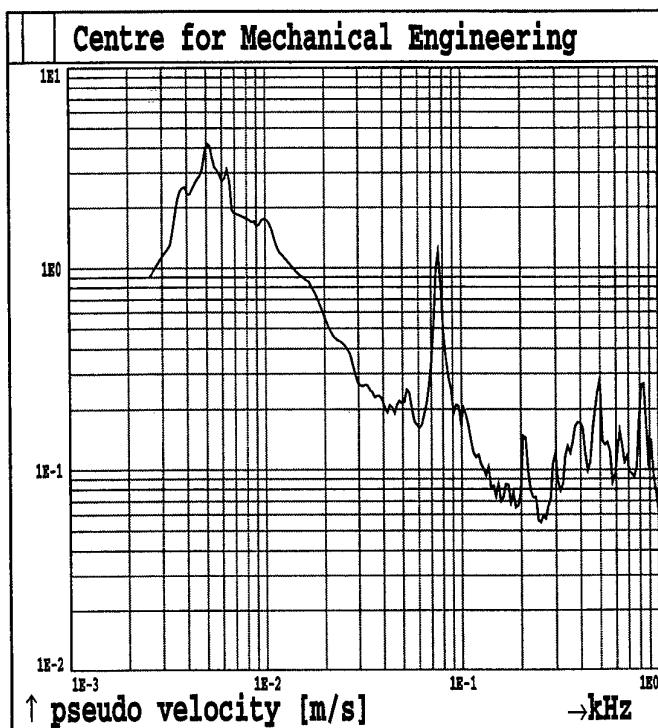
Fig.133. Shot 4 MAXIMAX Sensor A21

Fig.134. Shot 4 MAXIMAX Sensor A22

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↑ pseudo velocity [m/s]   →kHz
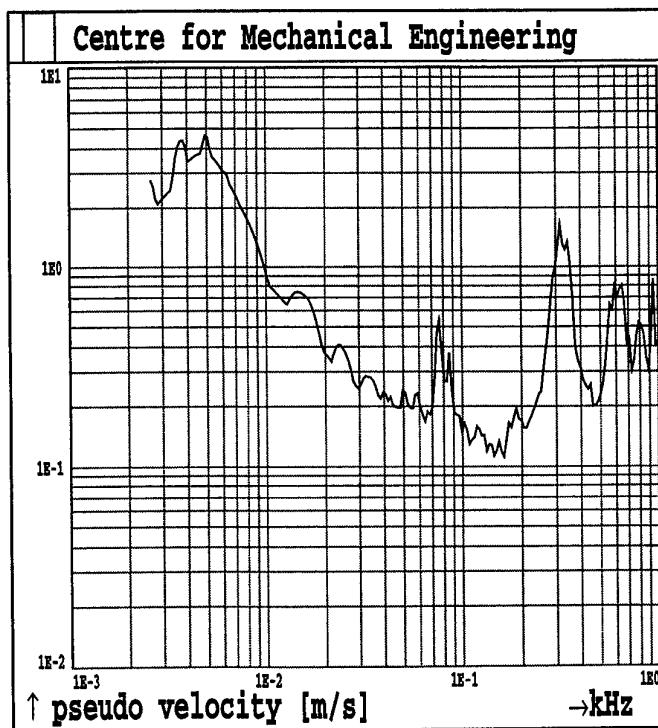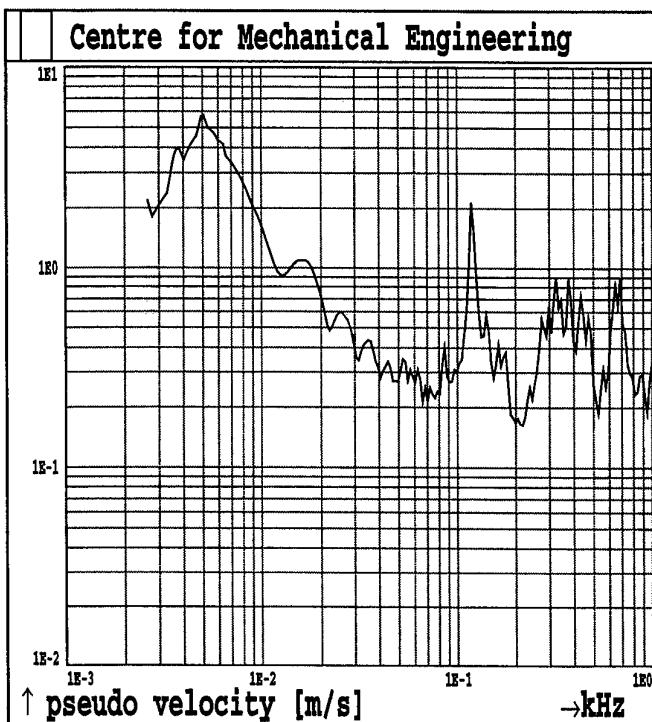
Fig.135. Shot 4 MAXIMAX Sensor A23

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↑ pseudo velocity [m/s]   →kHz
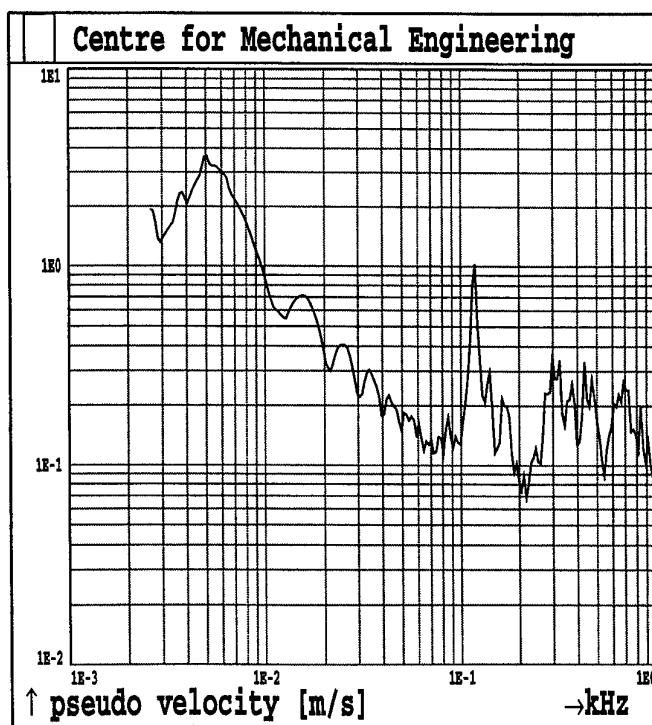
Fig.136. Shot 4 MAXIMAX Sensor A24

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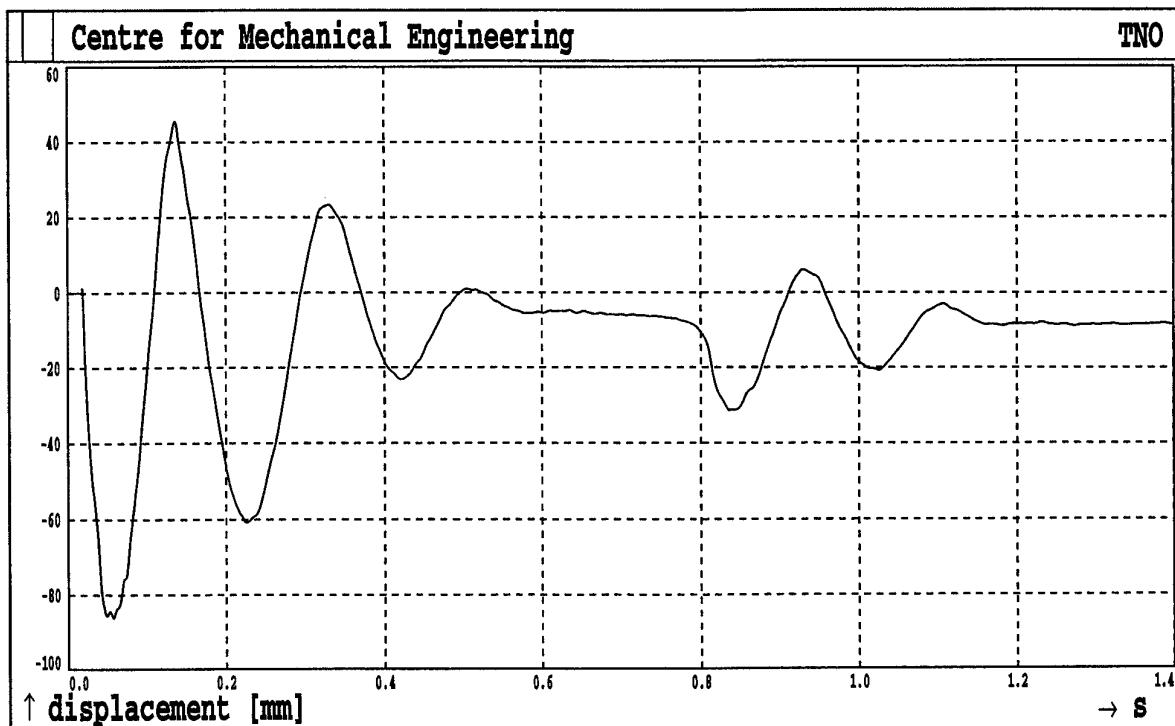
Fig.137. Shot 4 Sensor R1

Fig.138. Shot 4 Sensor R2

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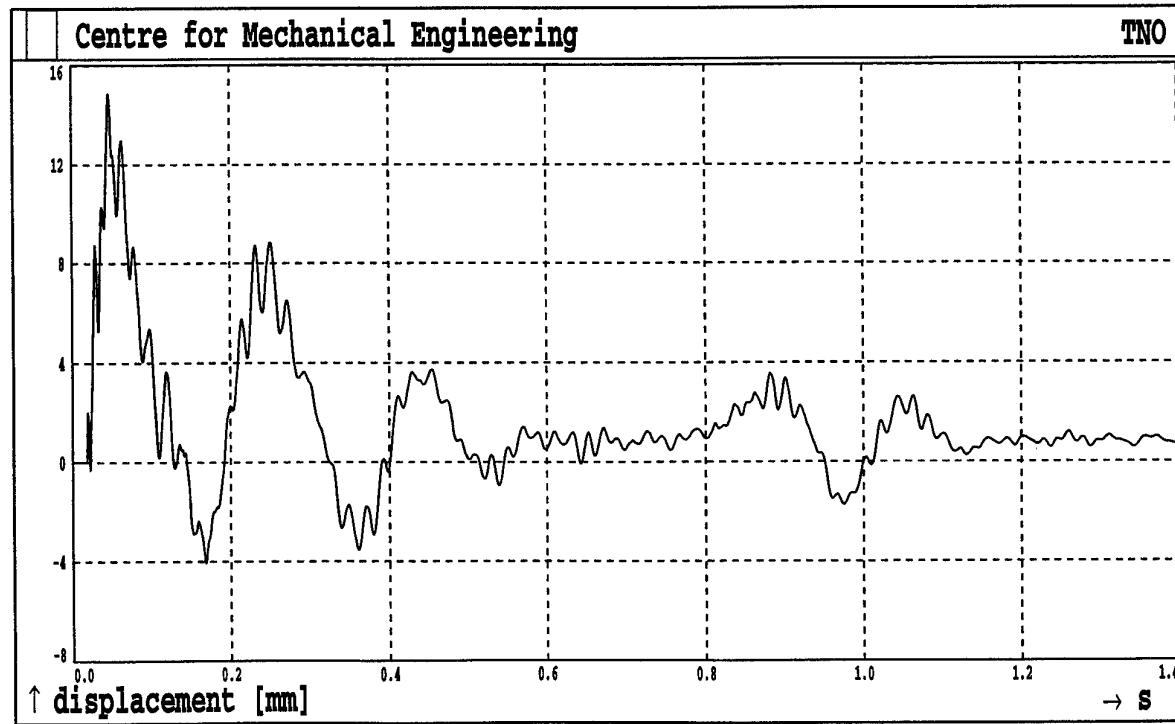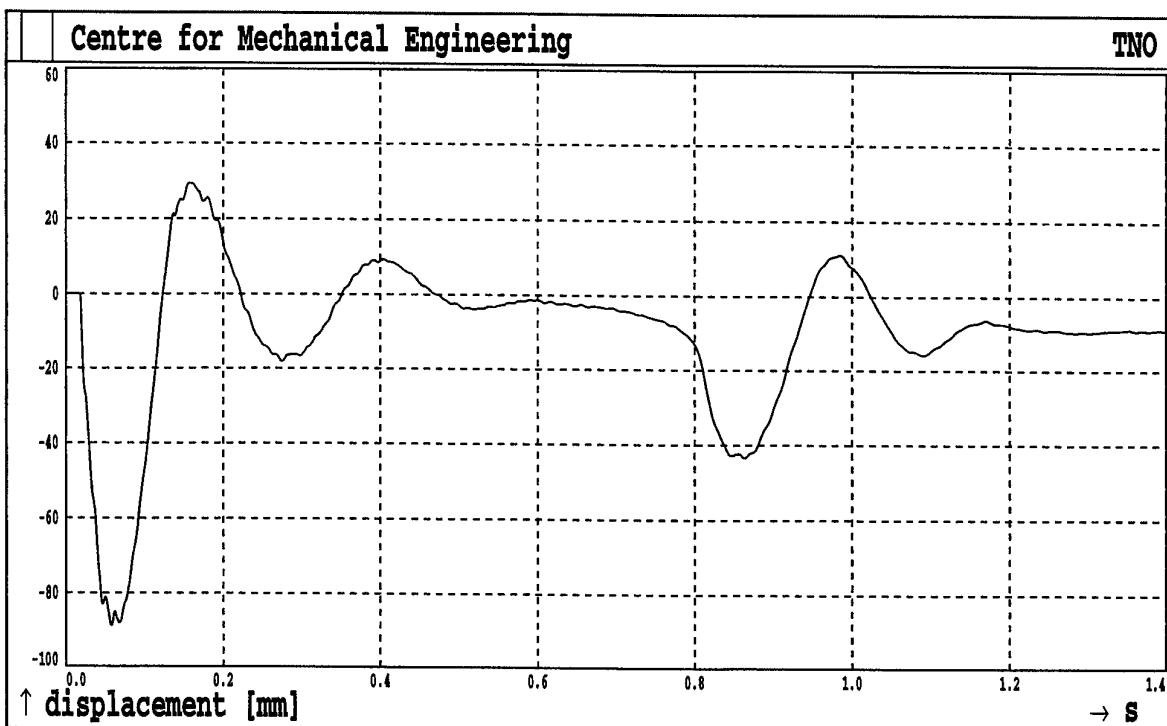
Fig.139. Shot 4   Sensor R3

Fig.140. Shot 4   Sensor R4

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↑ displacement [mm] →ms

Fig.141. Shot 4 Sensor R1

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↑ displacement [mm] →ms

Fig.142. Shot 4 Sensor R2

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↑ displacement [mm]   →ms

Fig.143. Shot 4   Sensor R3

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↑ displacement [mm]   →ms
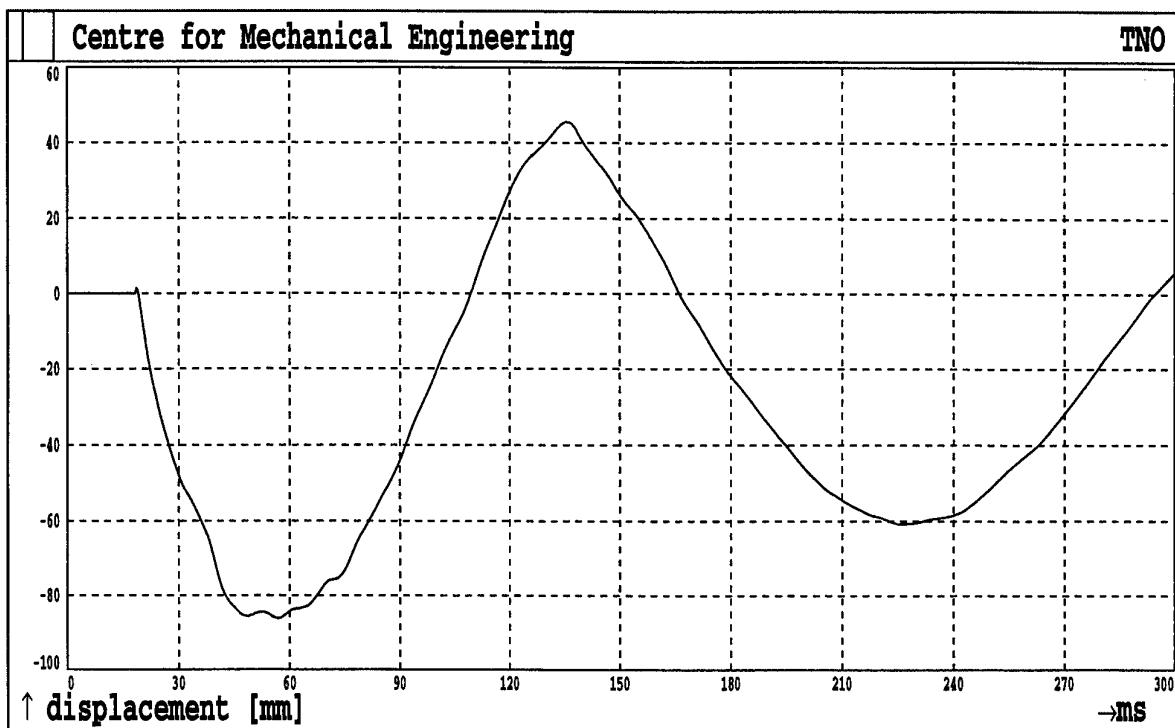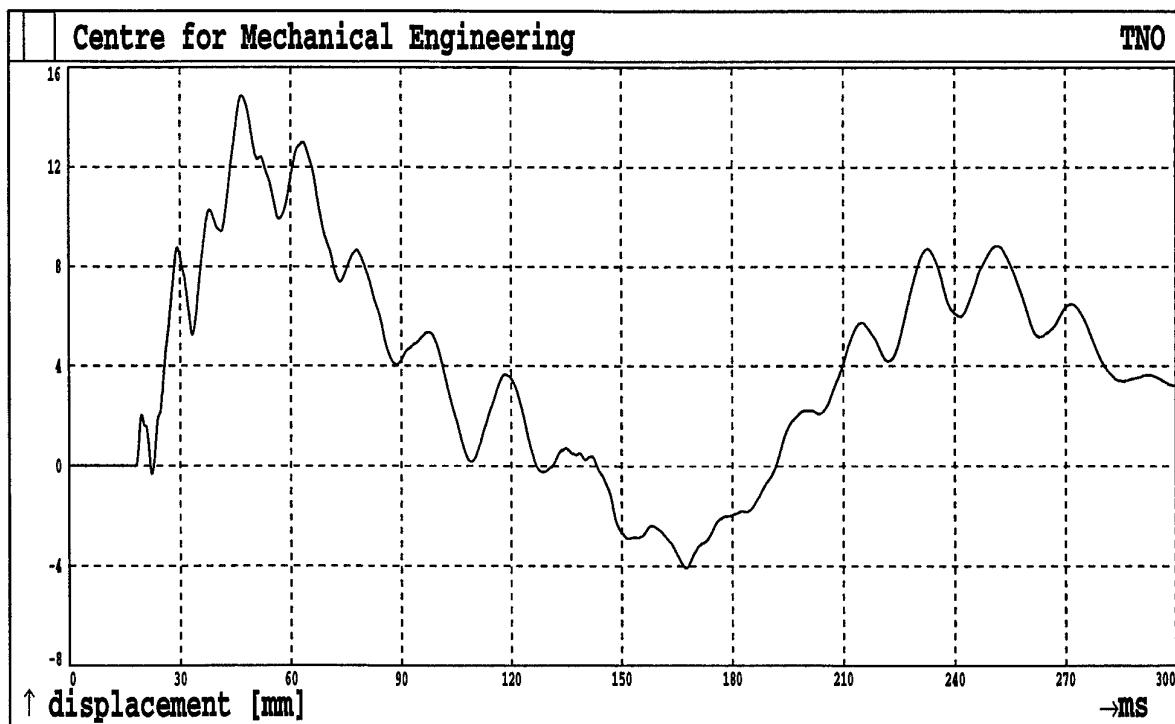
Fig.144. Shot 4   Sensor R4

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Fig.145. Shot 5 Sensor P1

Fig.146. Shot 5 Sensor P1

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Fig.147. Shot 5 Sensor P1

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↑ microstrain →ms

Fig.148. Shot 5   Sensor S1

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↑ microstrain →ms

Fig.149. Shot 5   Sensor S2

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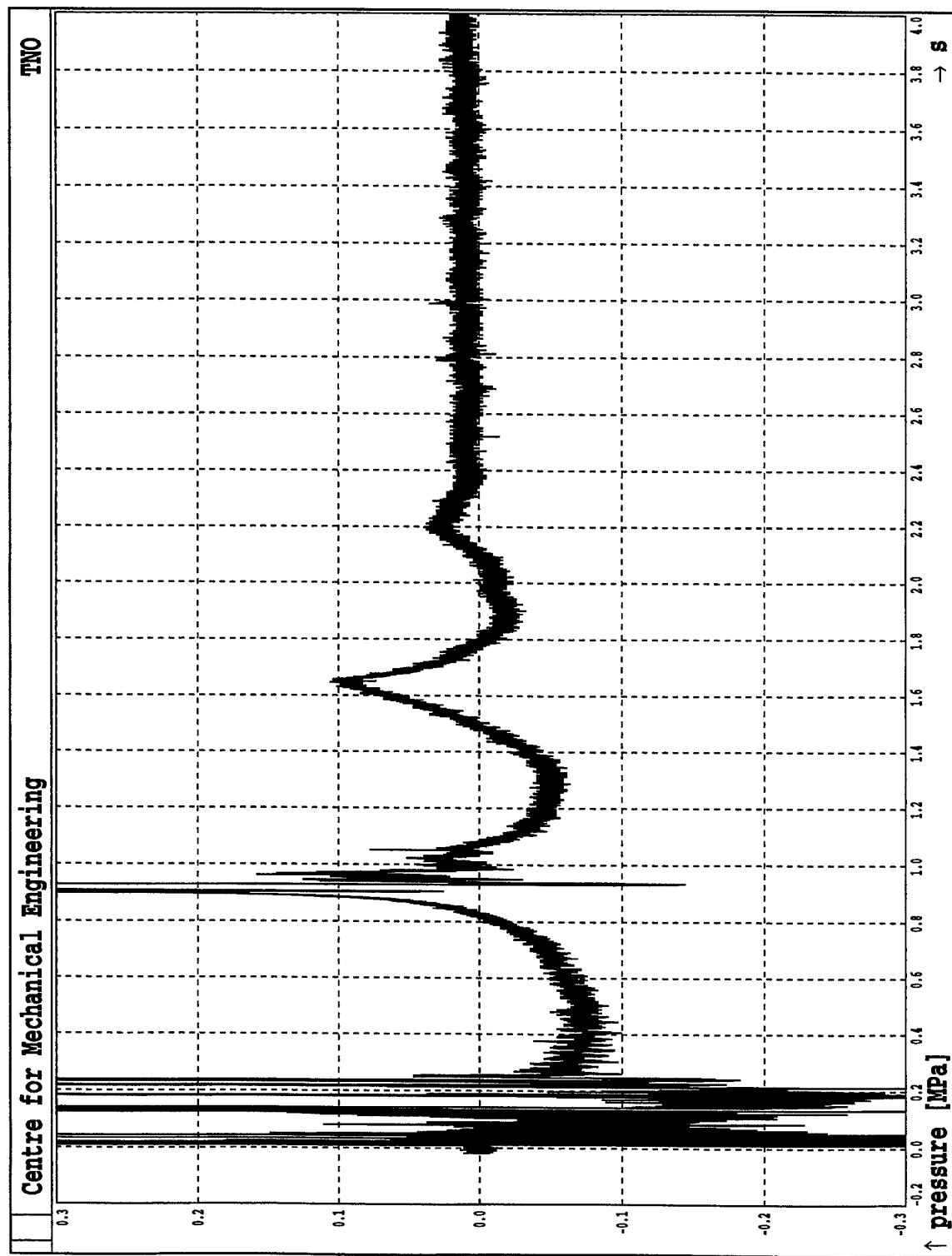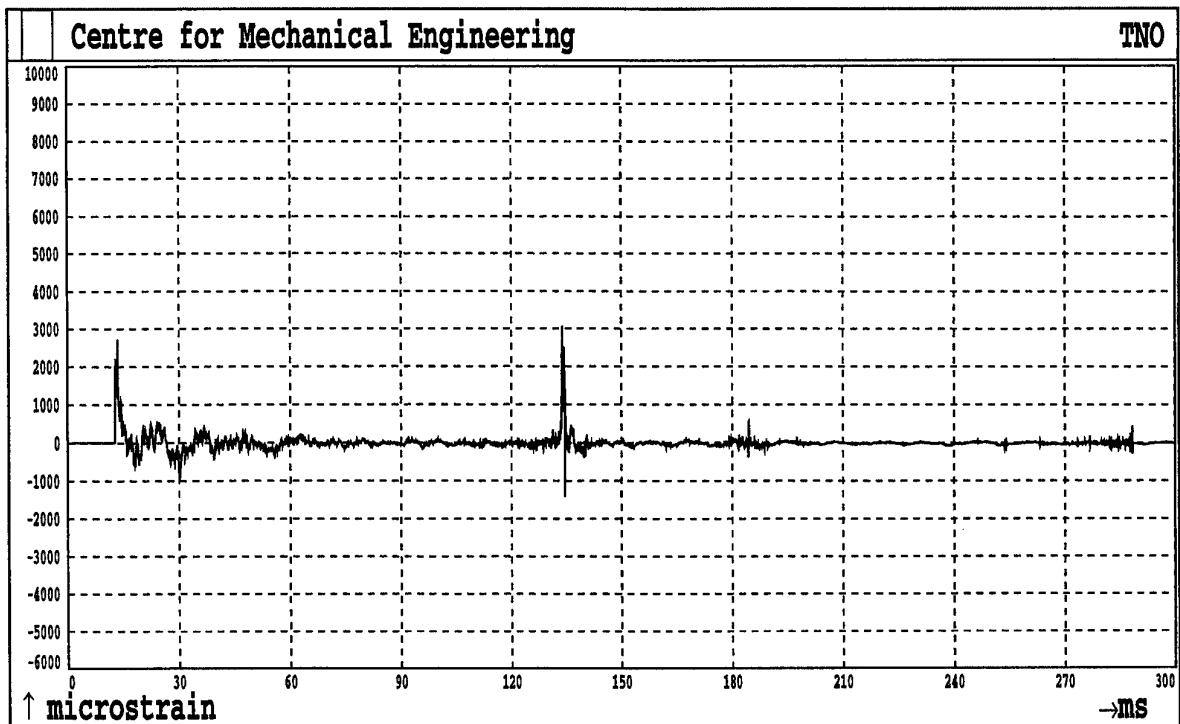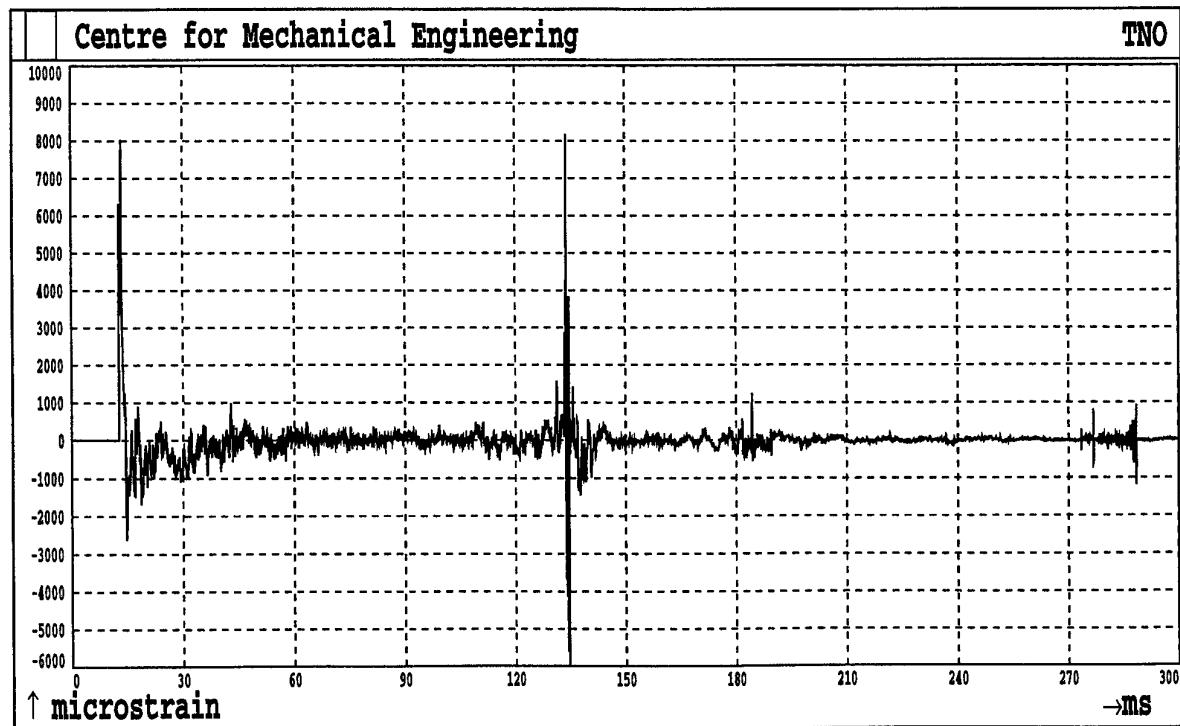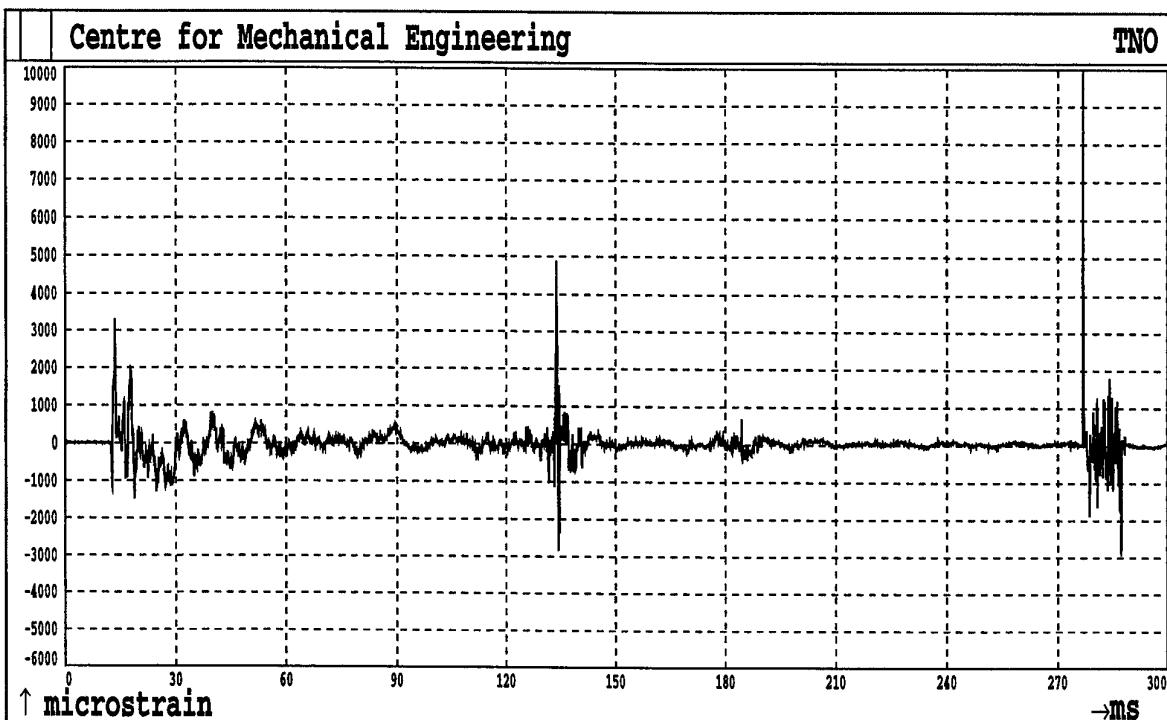
Fig.150. Shot 5 Sensor S3

Fig.151. Shot 5 Sensor S4

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Fig.152. Shot 5   Sensor S5

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Fig.153. Shot 5   Sensor S6

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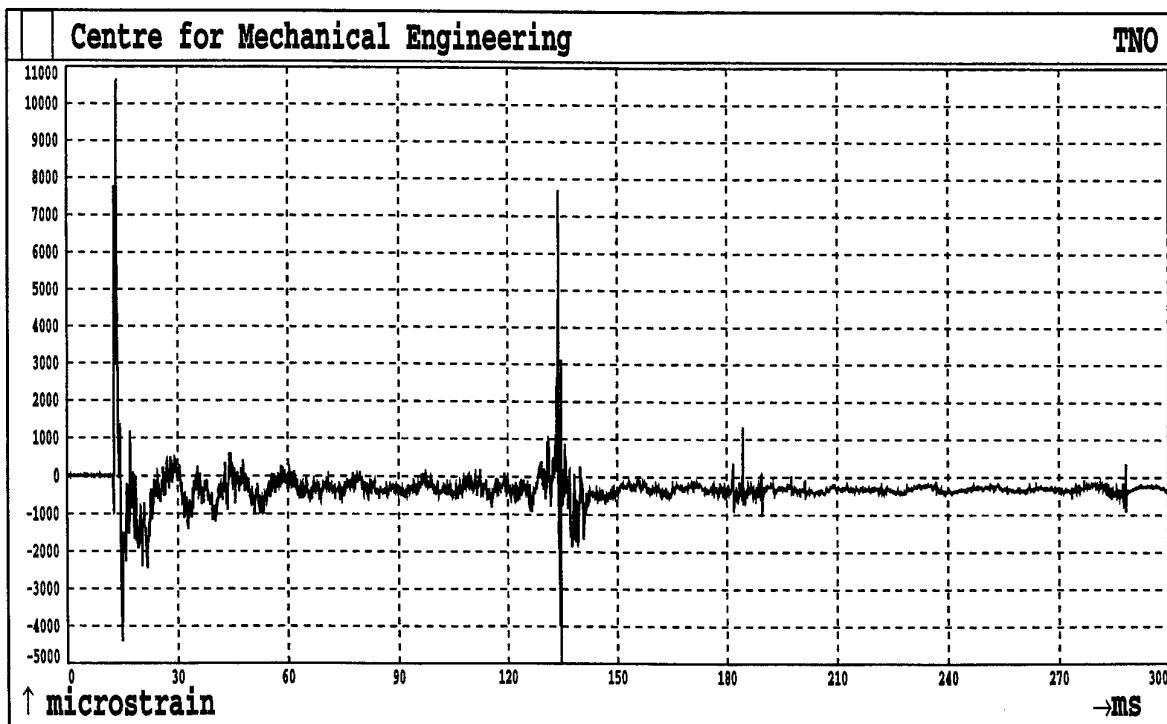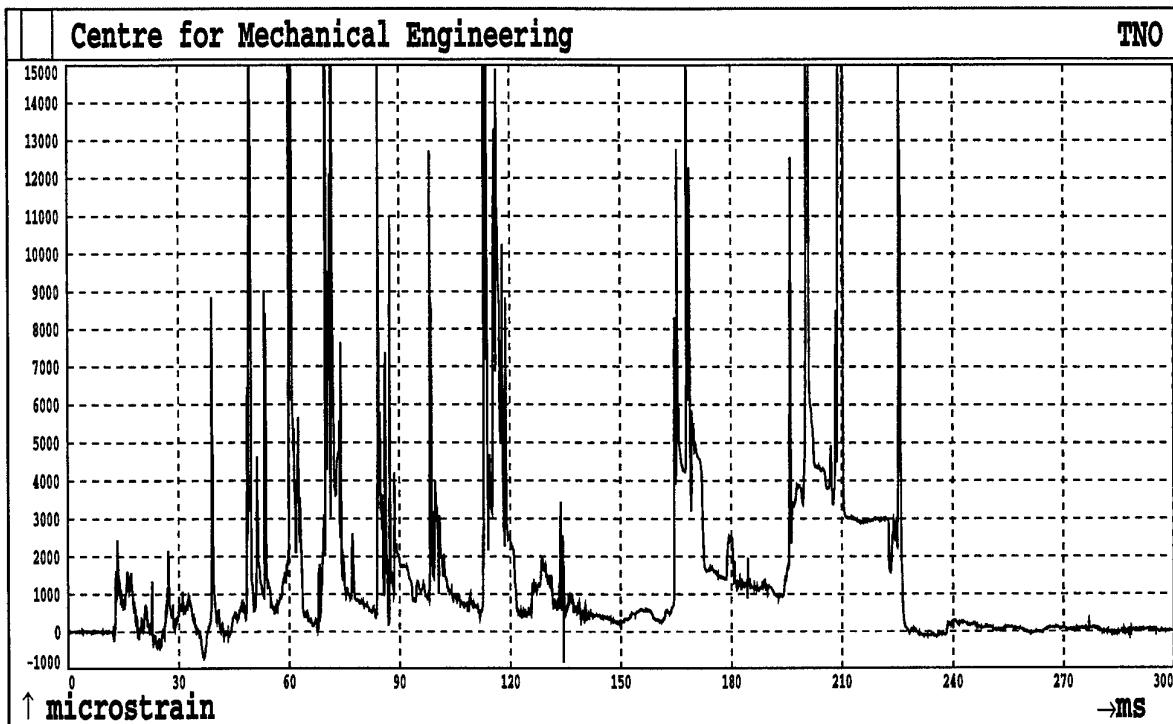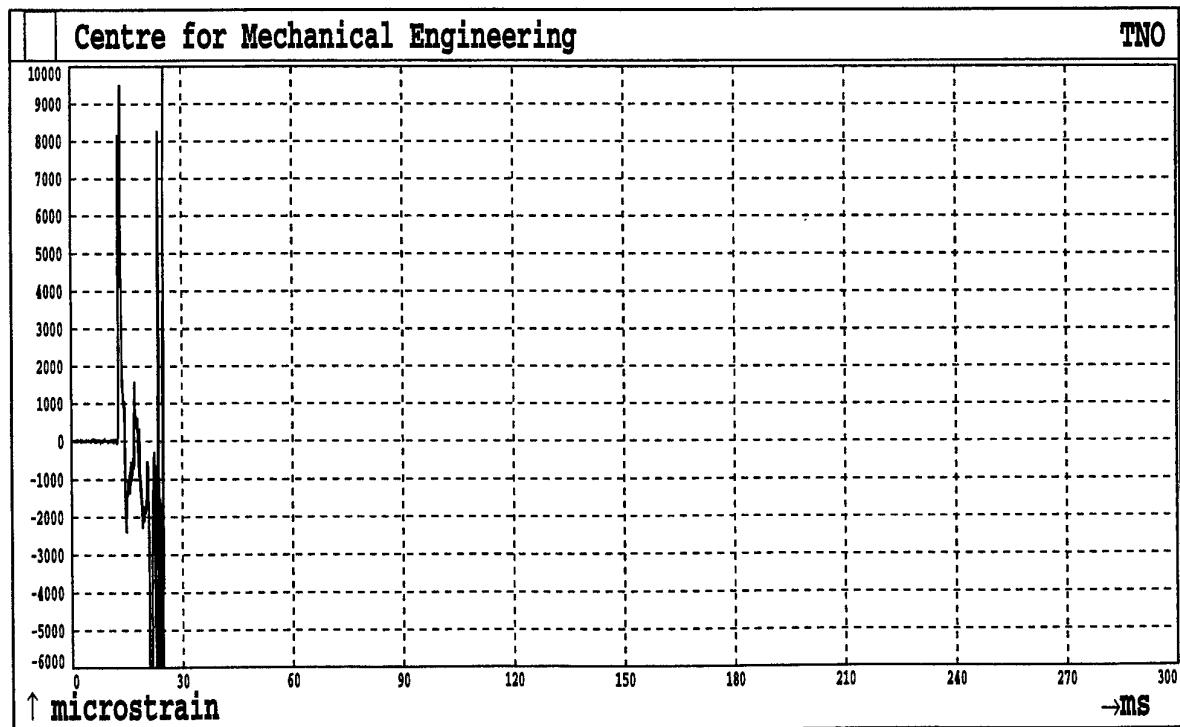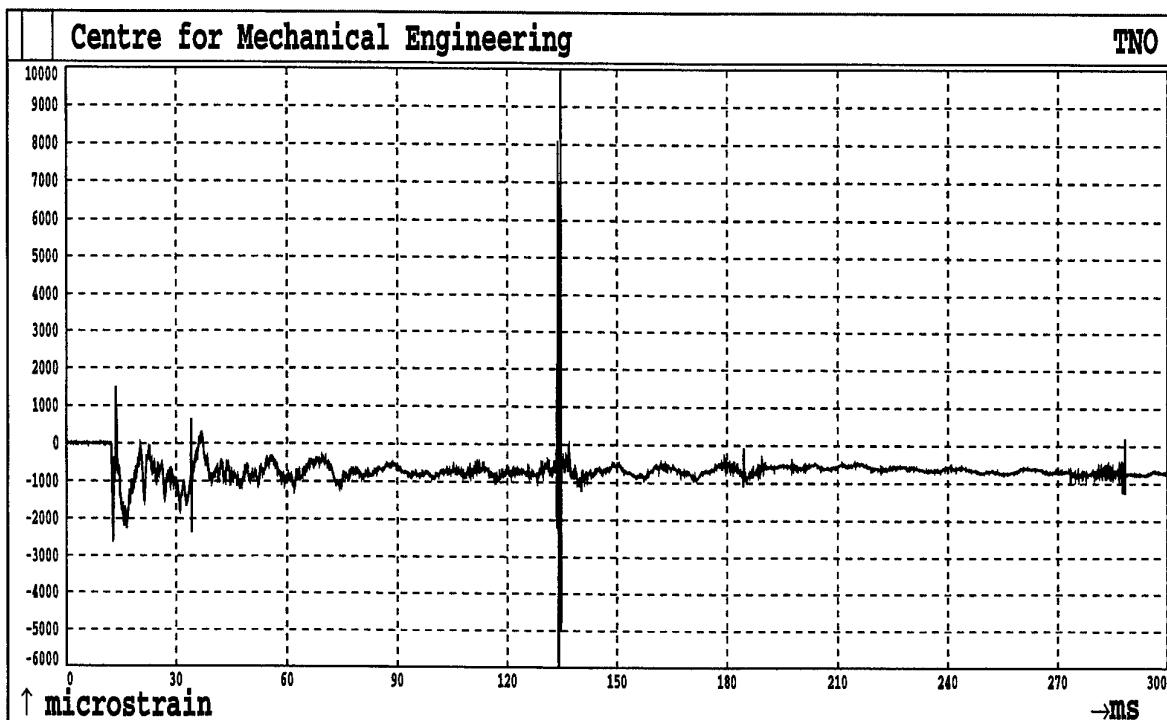
Fig.154. Shot 5   Sensor S7

Fig.155. Shot 5   Sensor S8

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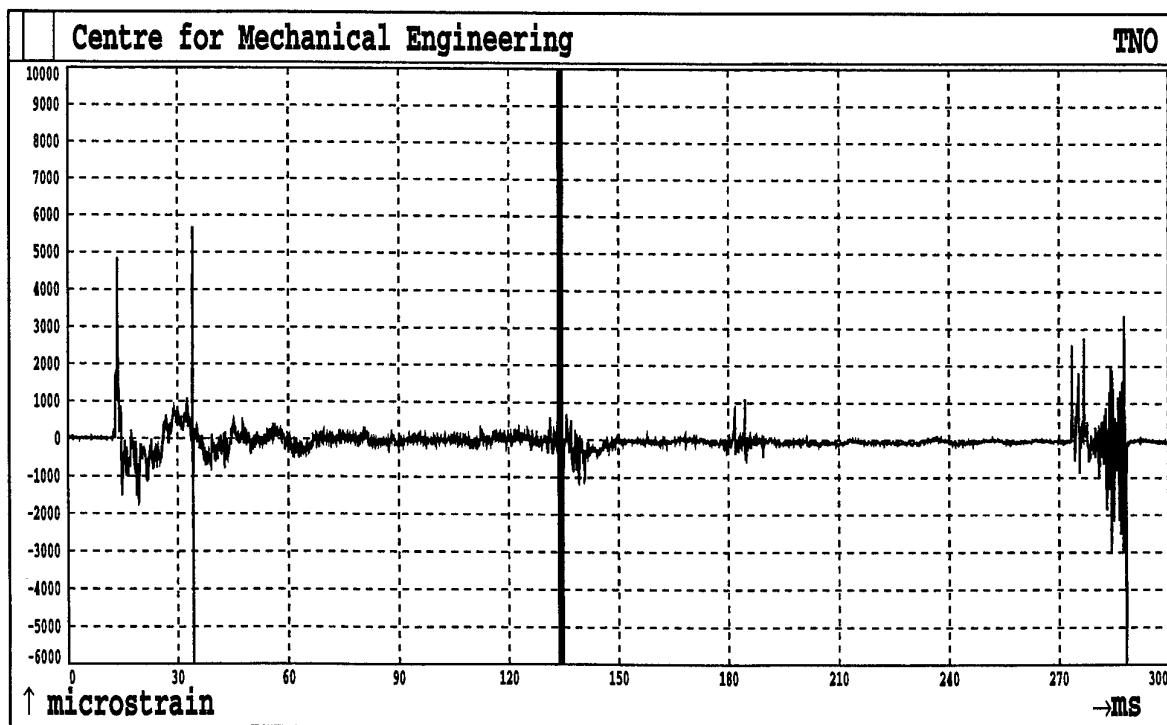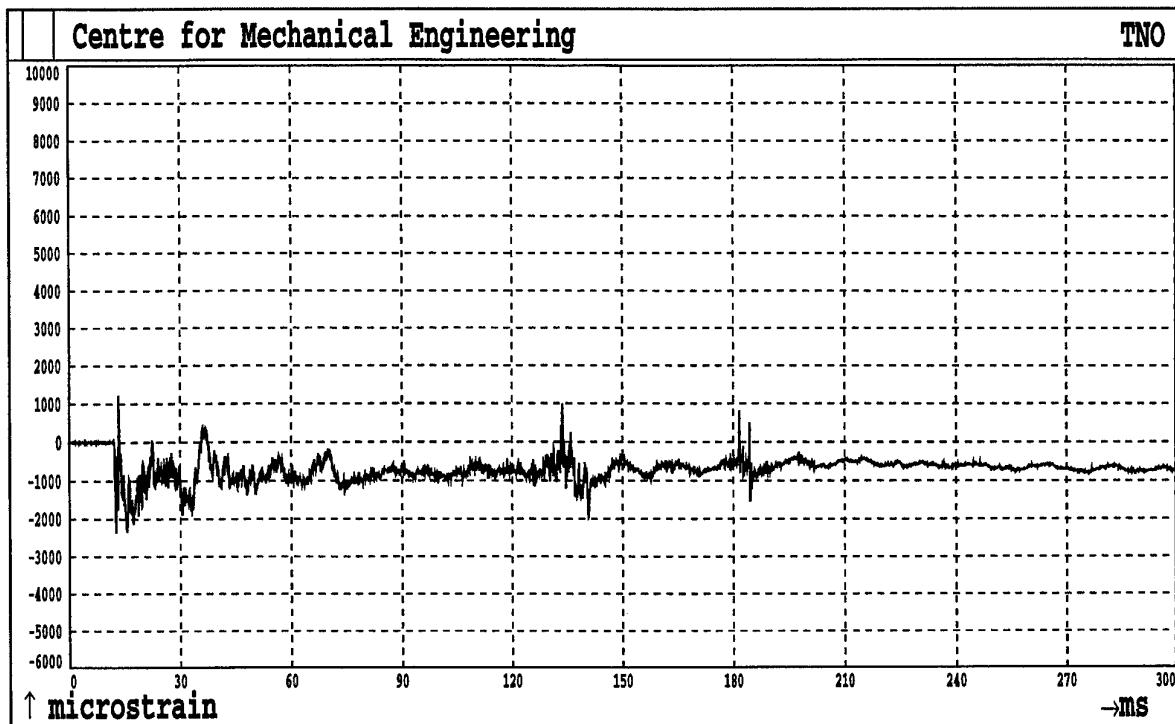
Fig.156. Shot 5 Sensor S11

Fig.157. Shot 5 Sensor S12

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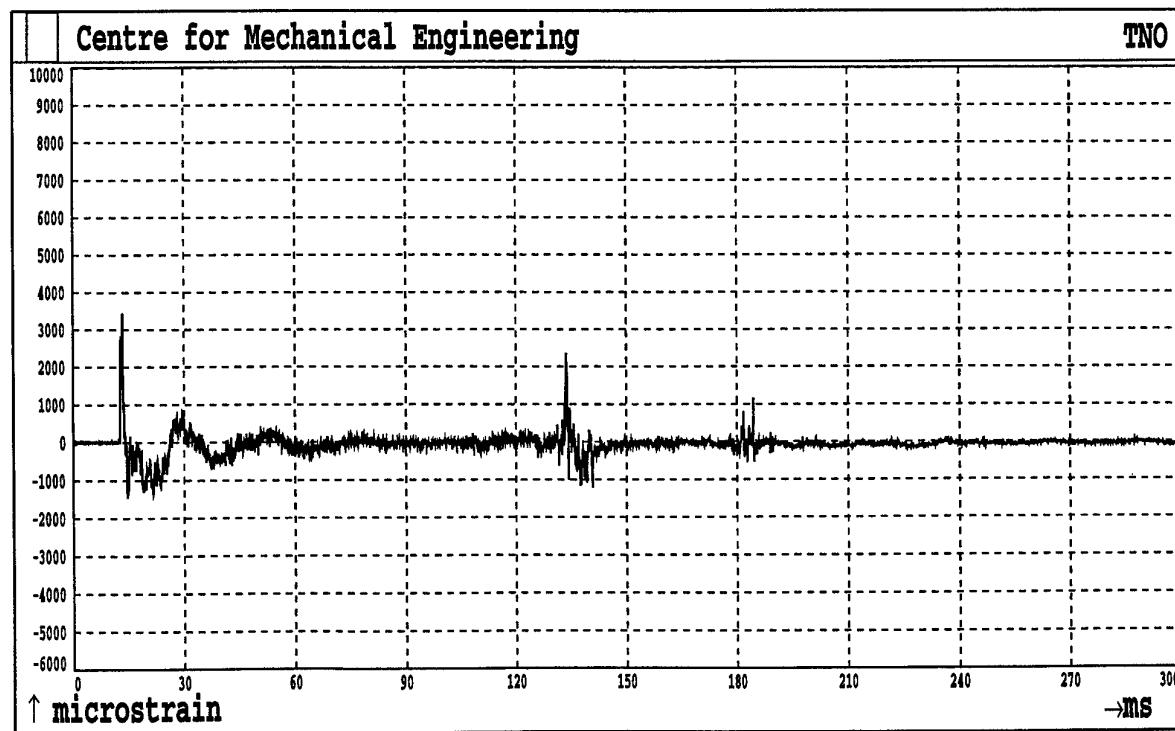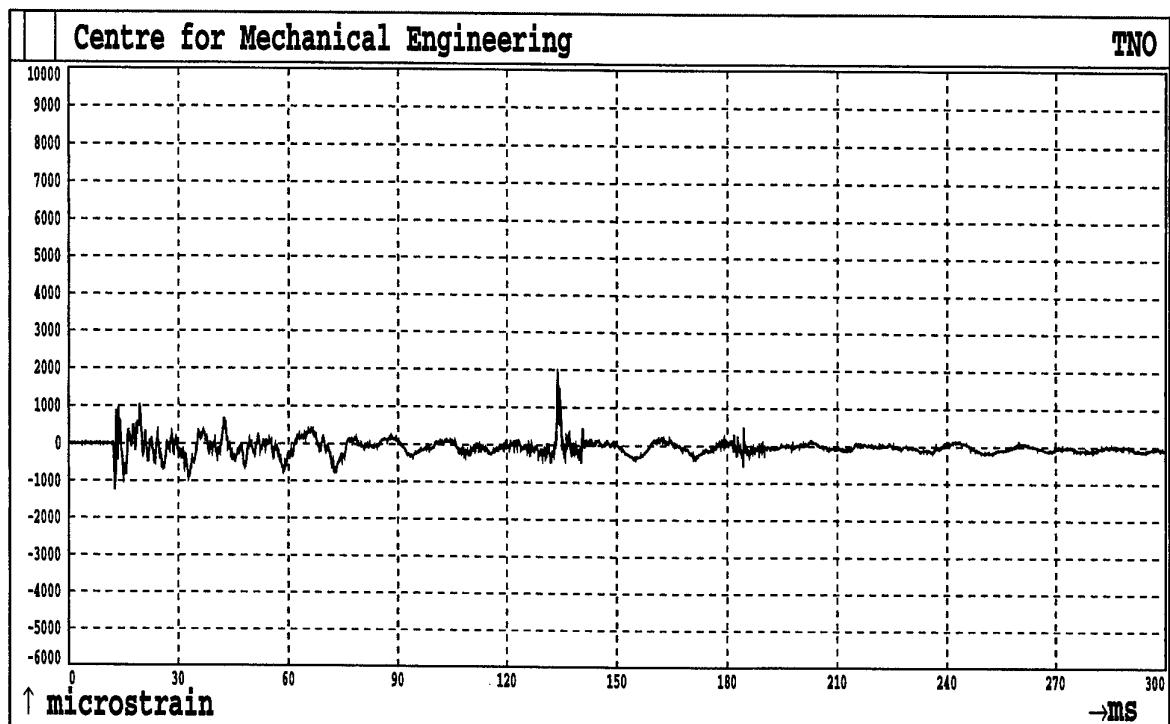
Fig.158. Shot 5   Sensor S13

Fig.159. Shot 5   Sensor S14

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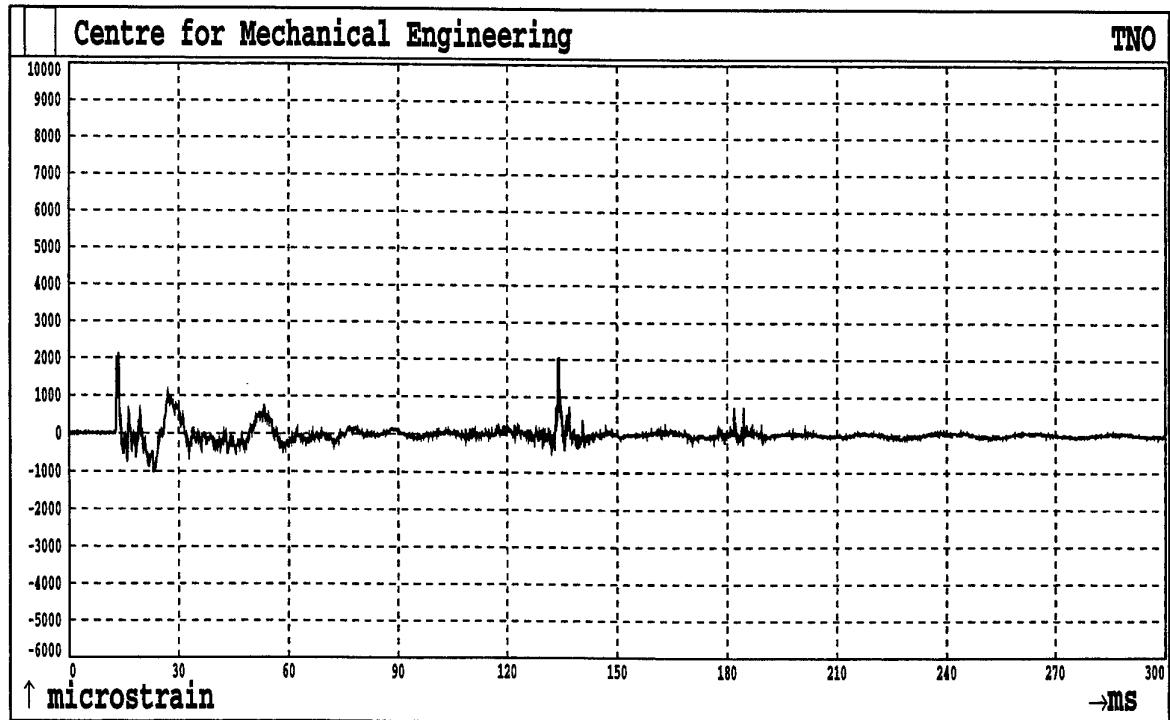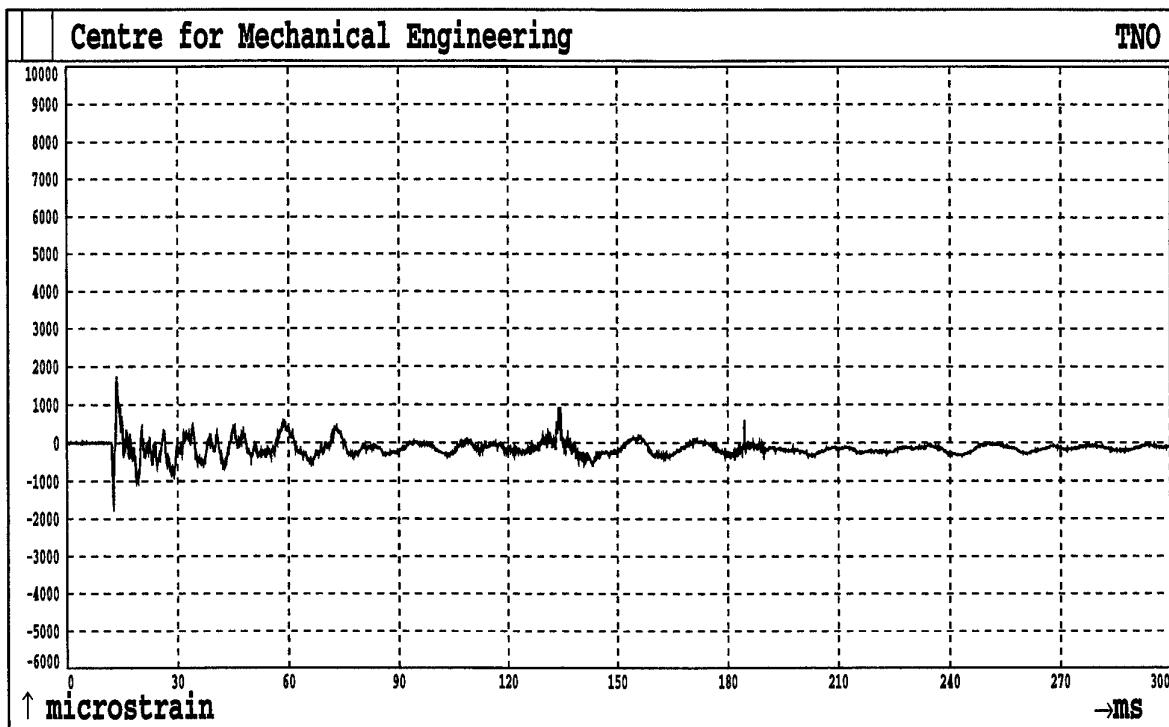
Fig.160. Shot 5   Sensor S15

Fig.161. Shot 5   Sensor S16

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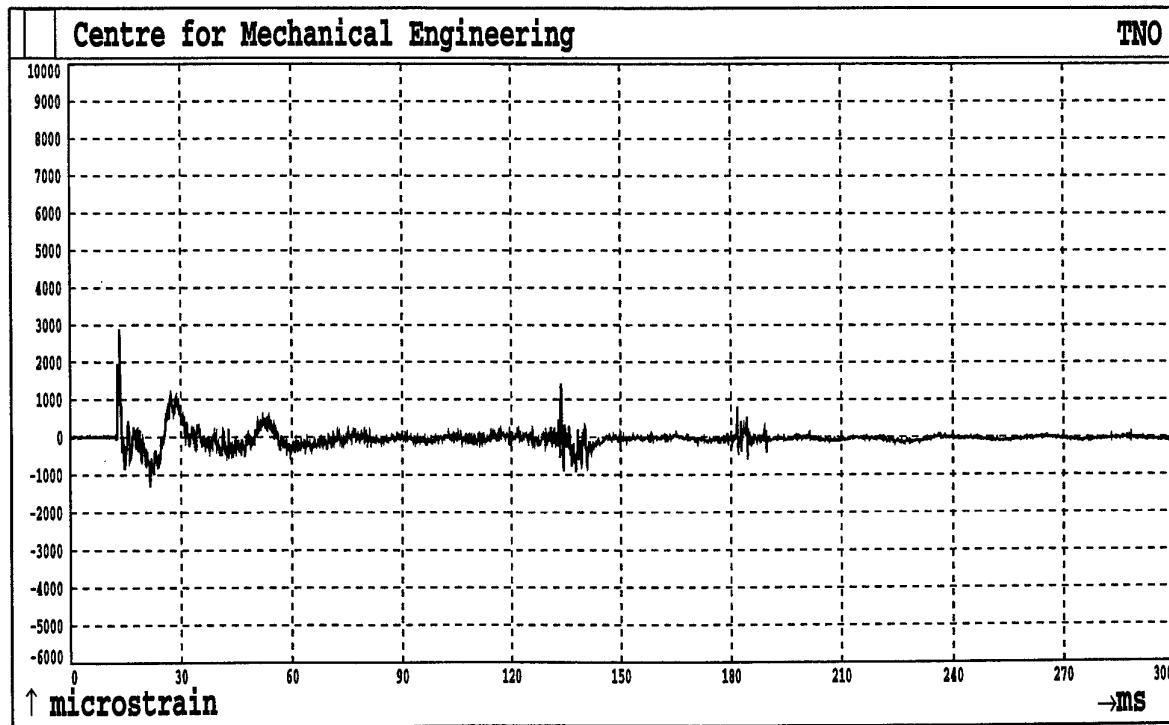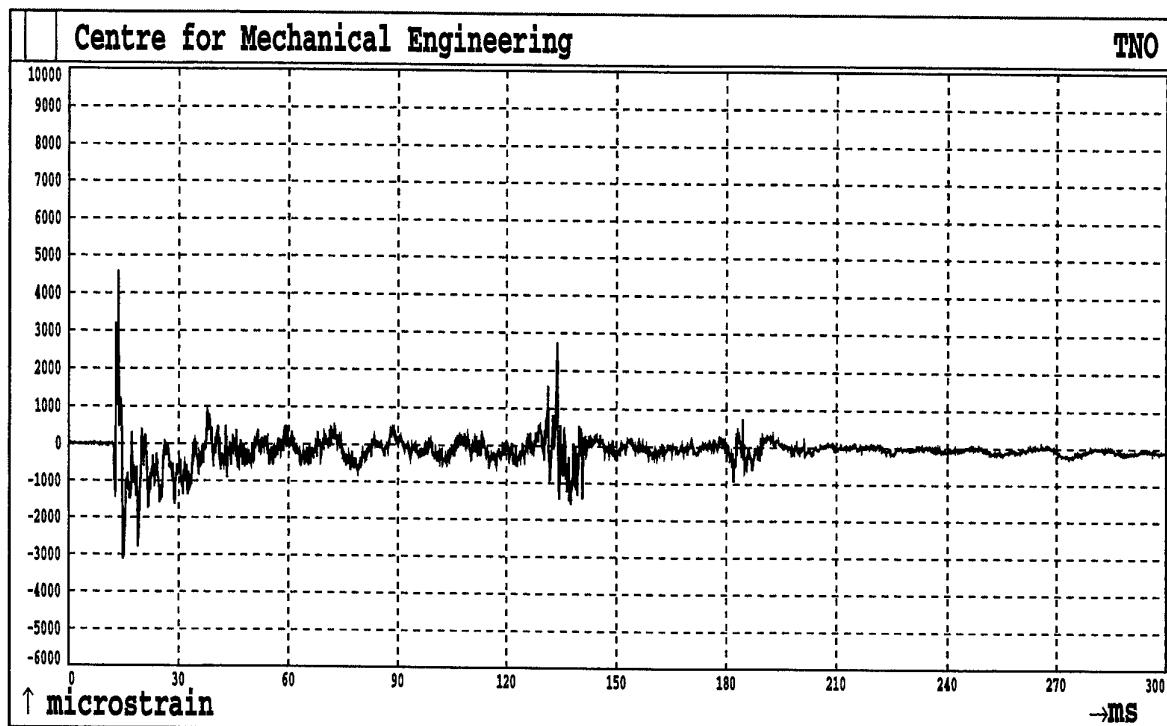
Fig.162. Shot 5   Sensor S17

Fig.163. Shot 5   Sensor S18
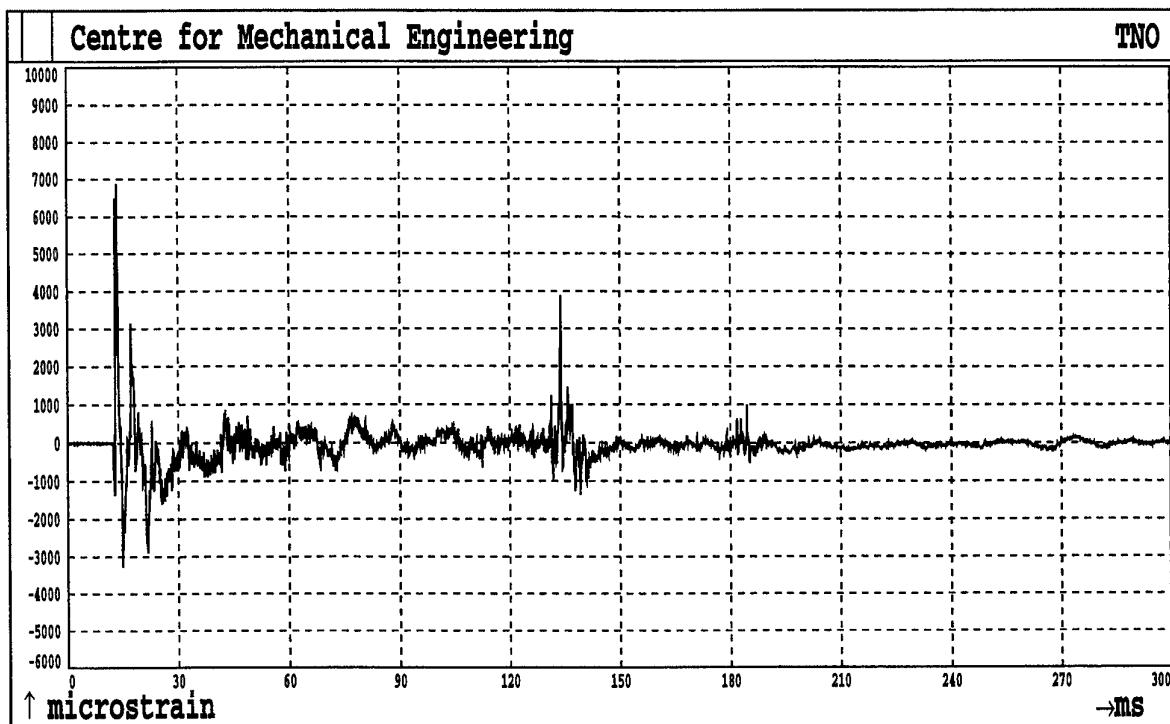
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Fig.164. Shot 5   Sensor S19

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Fig.165. Shot 5   Sensor S20

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↑ microstrain   →ms

Fig.166. Shot 5 Sensor S21

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↑ microstrain   →ms

Fig.167. Shot 5 Sensor S22

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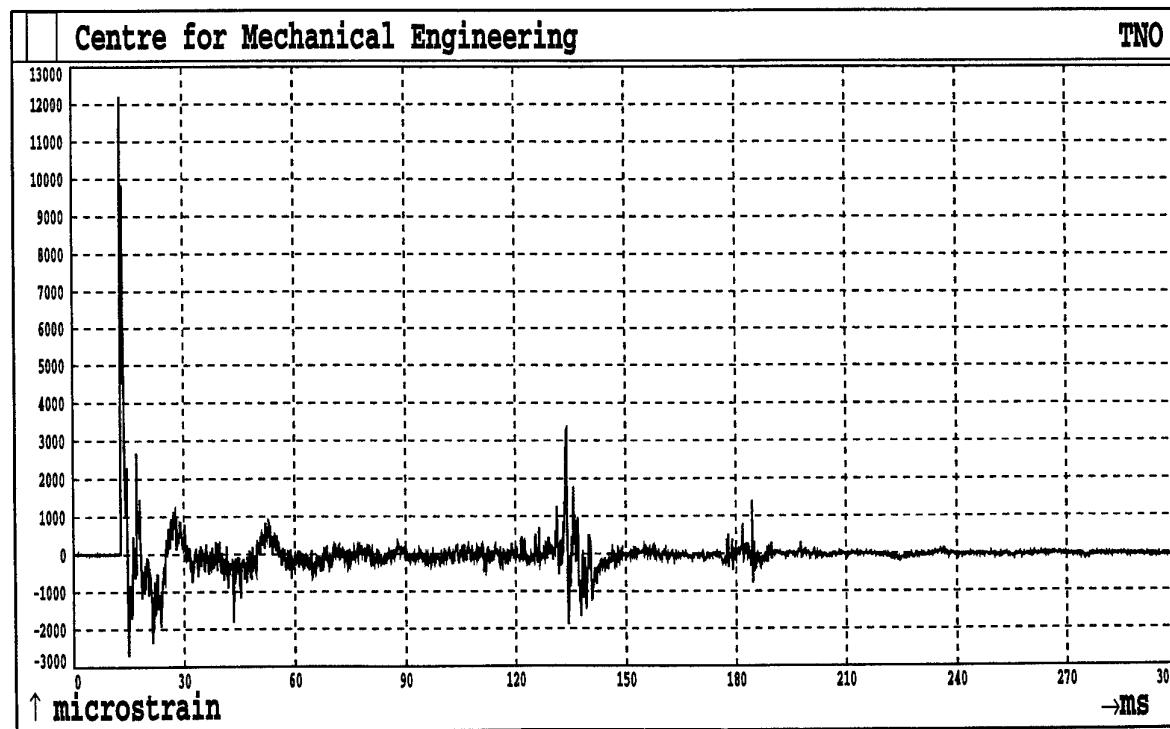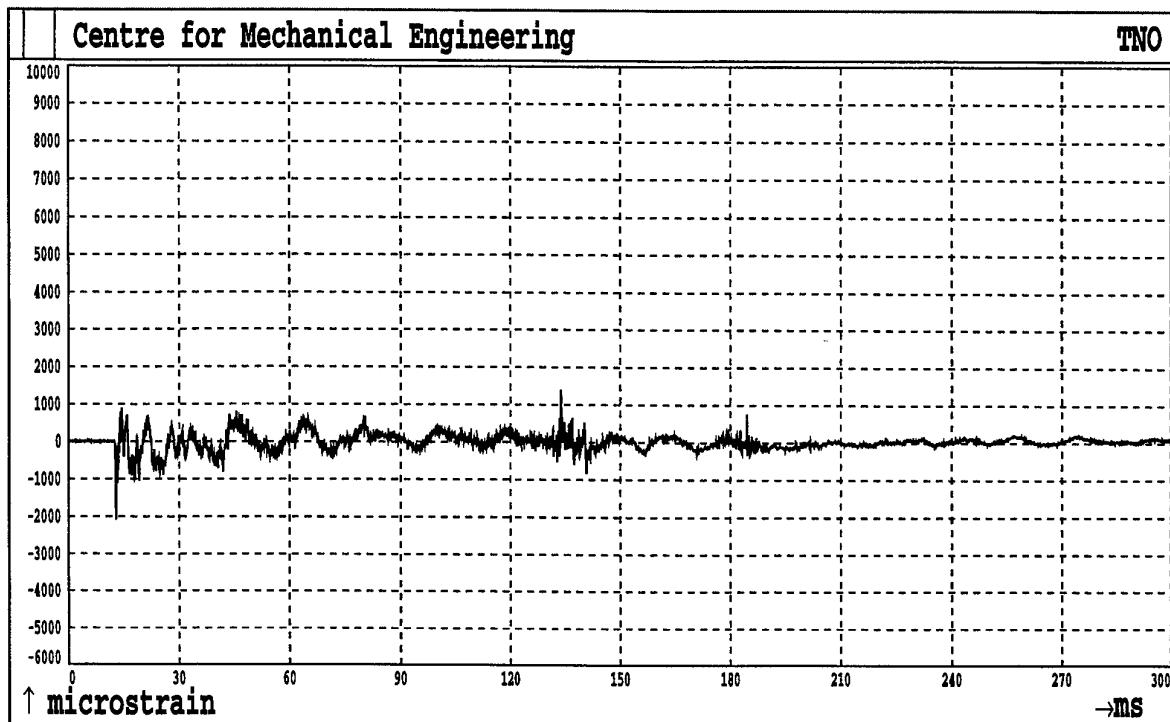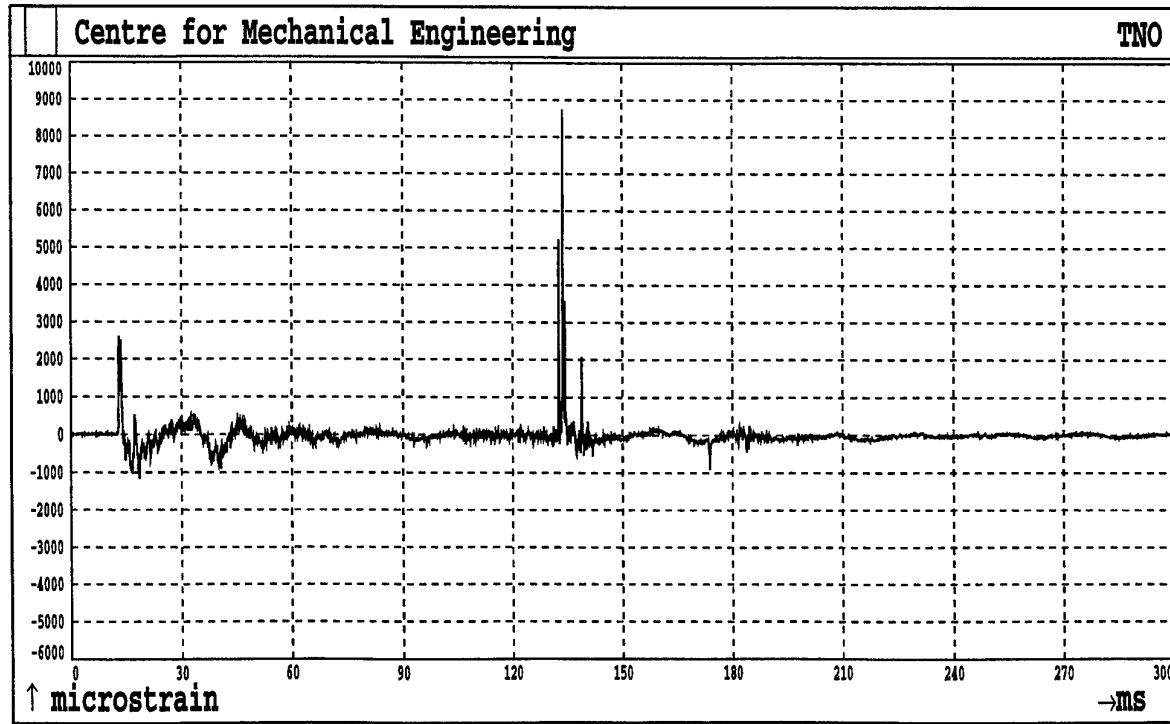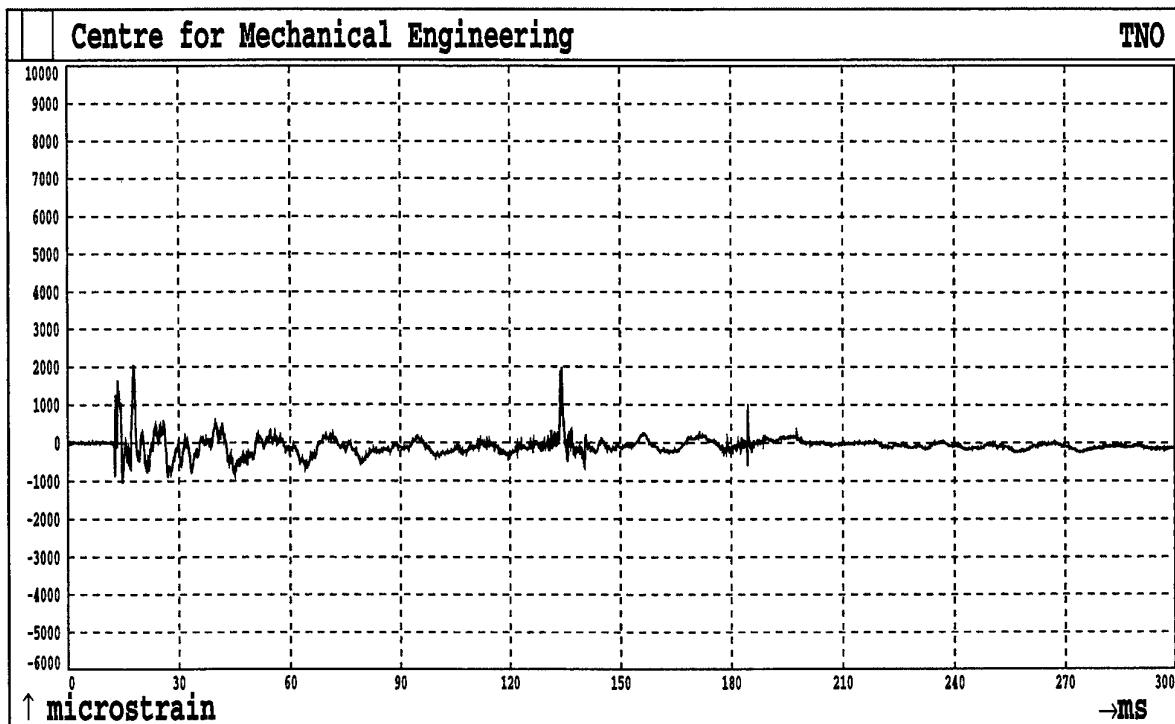
Fig.168. Shot 5   Sensor S23

Fig.169. Shot 5   Sensor S24

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Fig.170. Shot 5 Sensor S25

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Fig.171. Shot 5 Sensor S26

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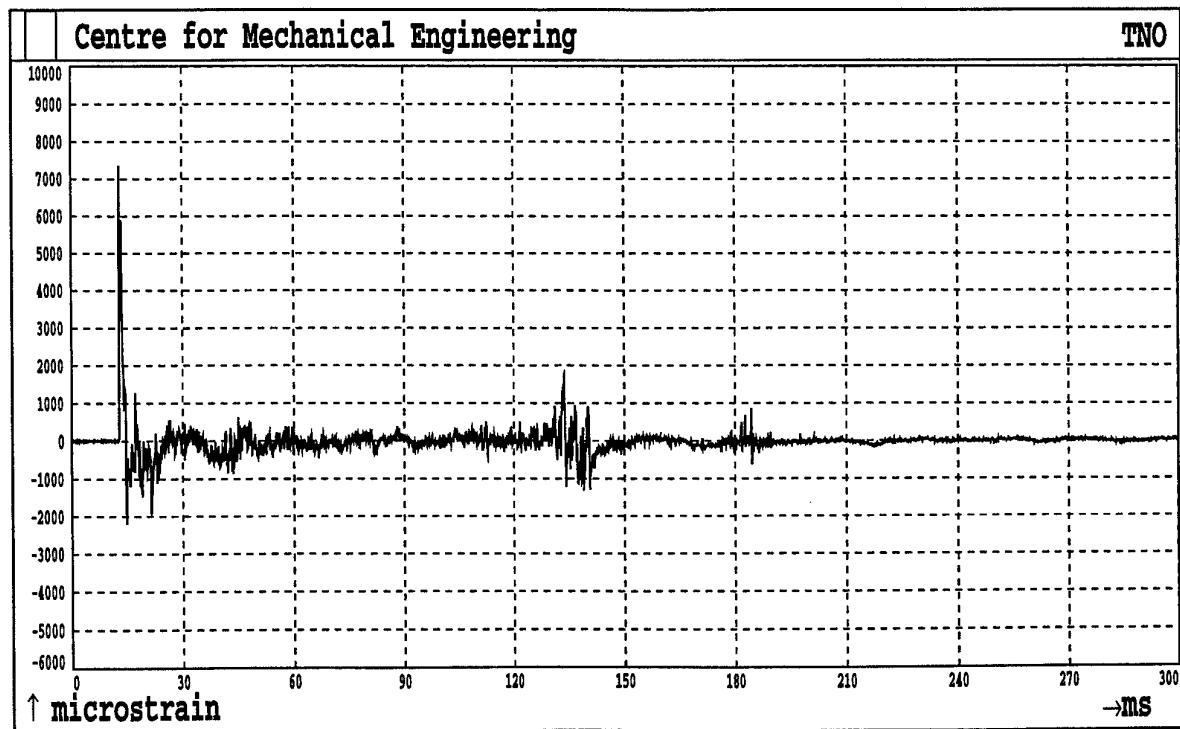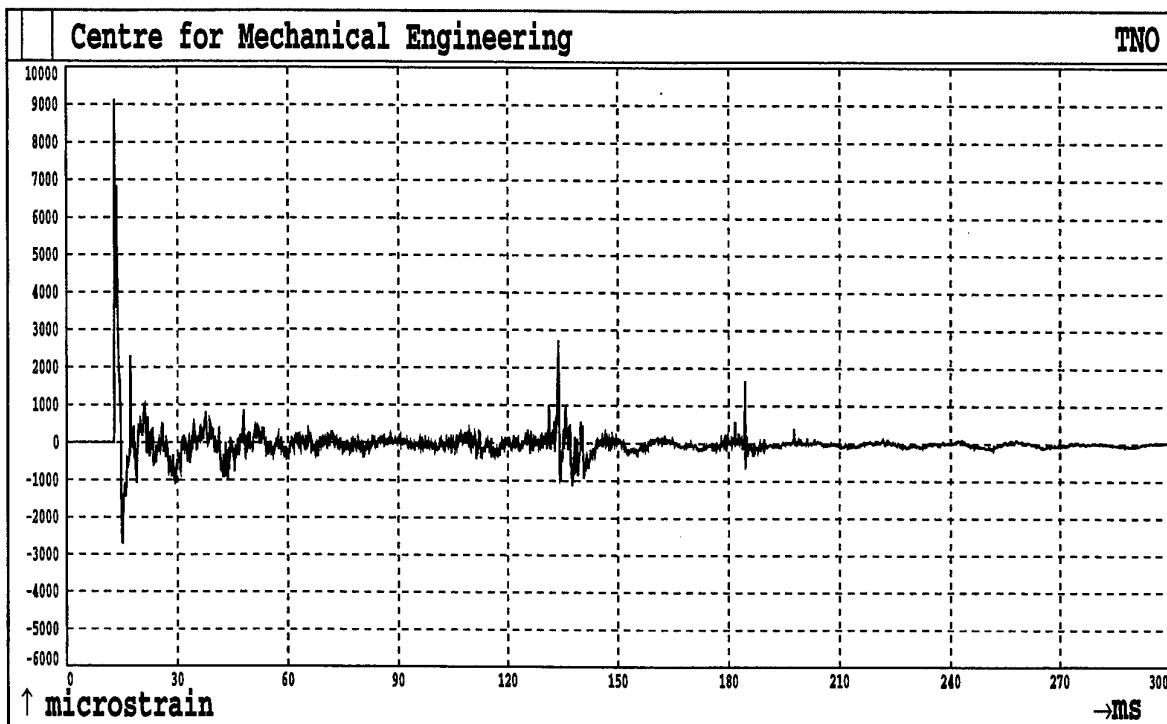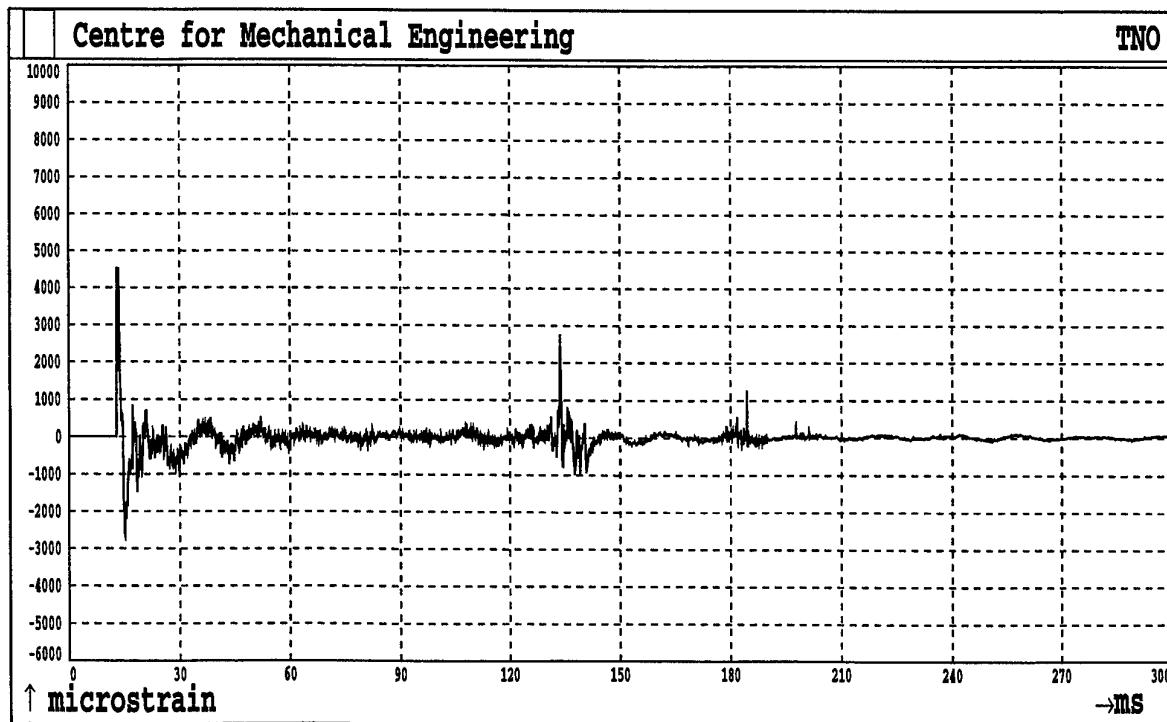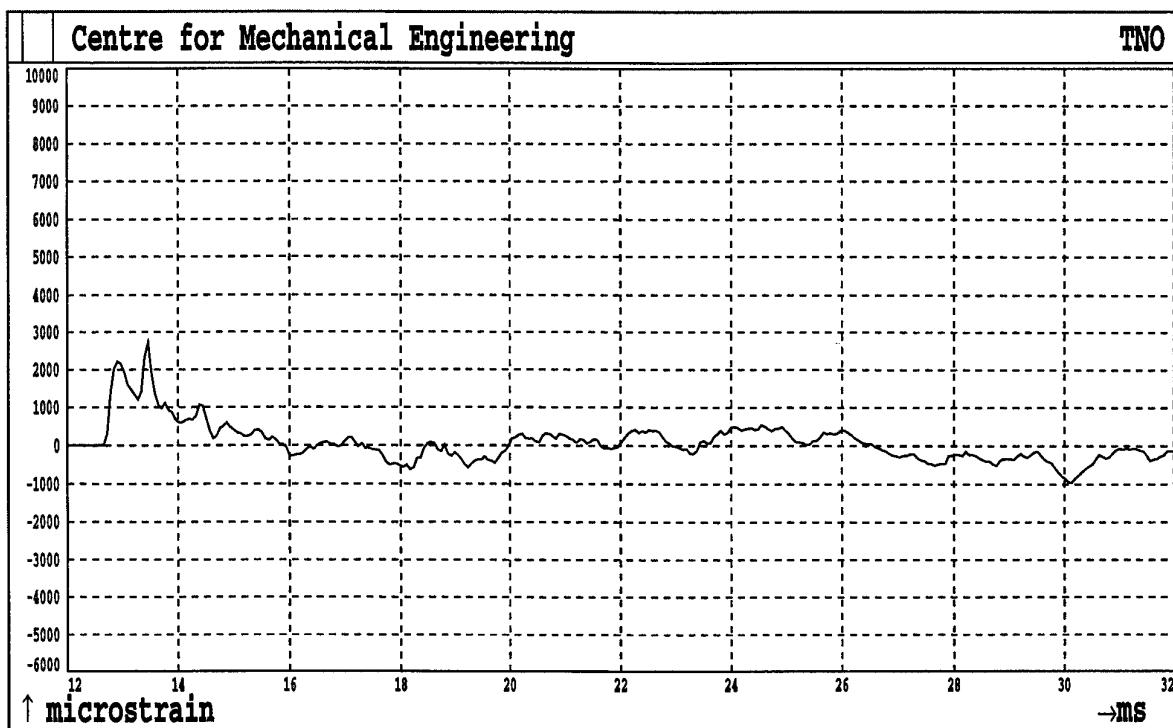
Fig.172. Shot 5   Sensor S1

Fig.173. Shot 5   Sensor S2
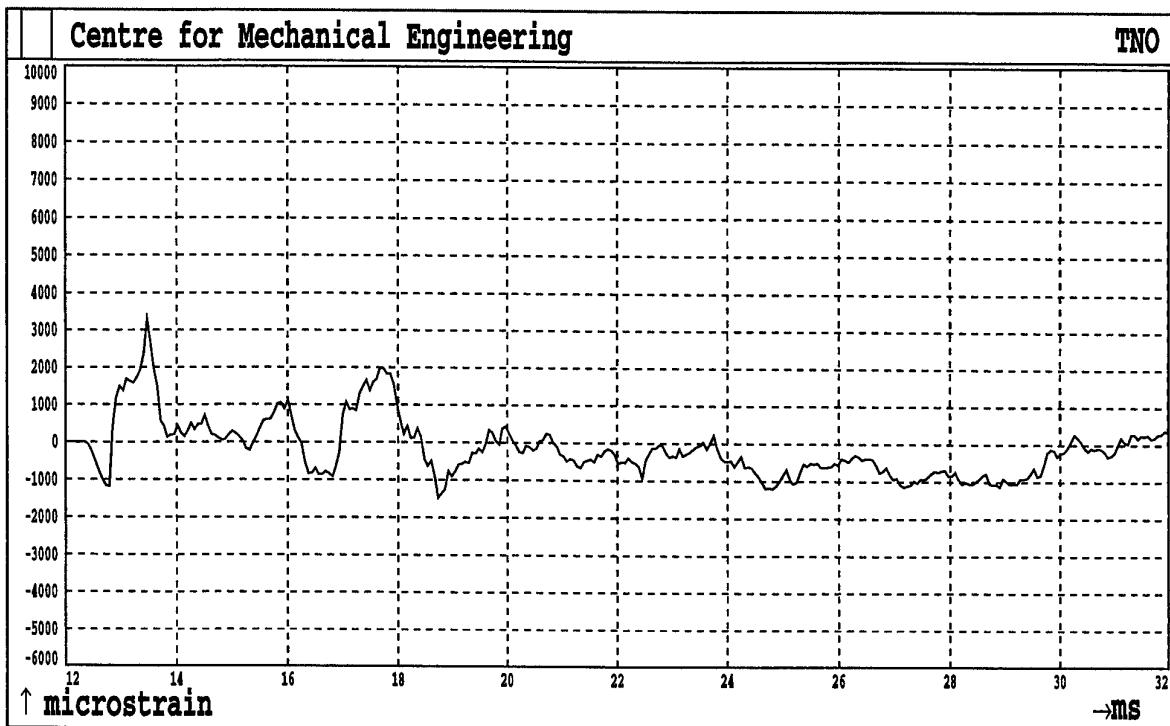
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Fig.174. Shot 5   Sensor S3

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Fig.175. Shot 5   Sensor S4

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Fig.176. Shot 5   Sensor S5

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Fig.177. Shot 5   Sensor S6

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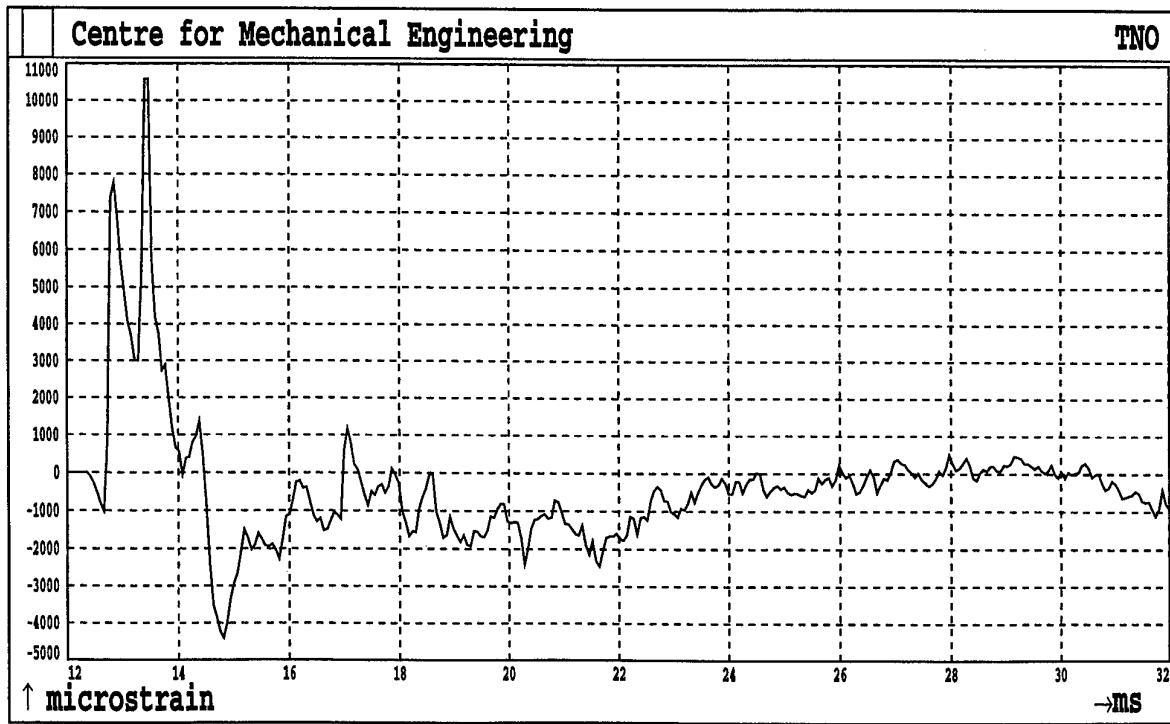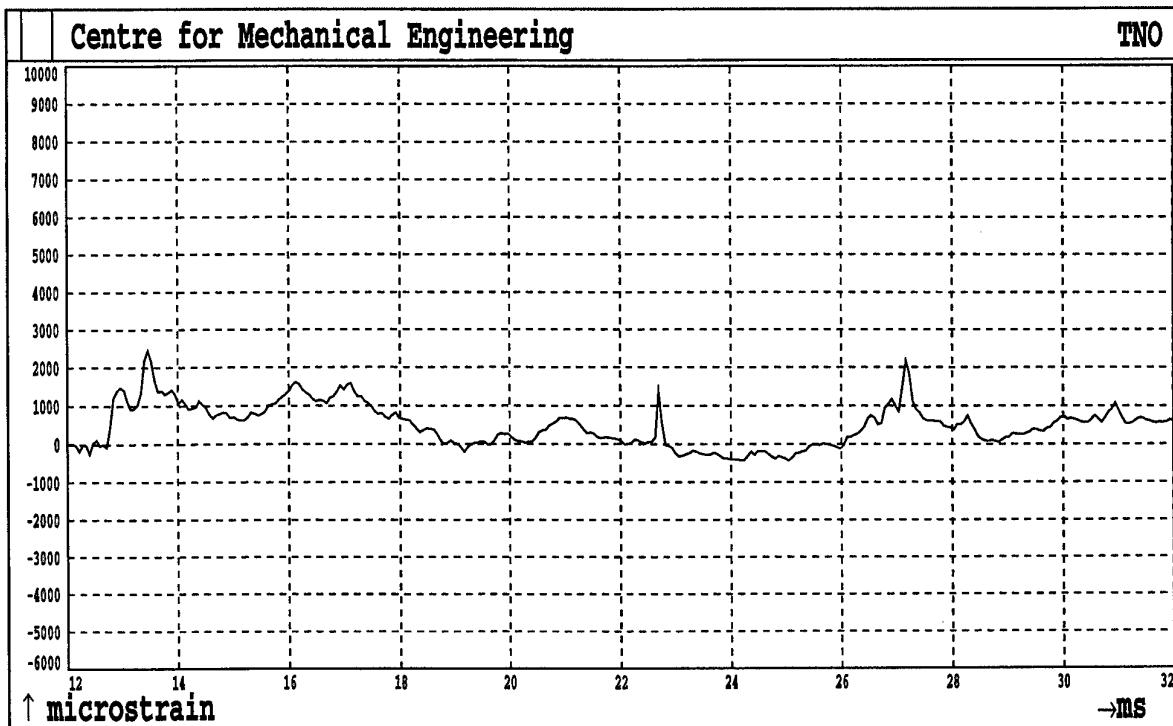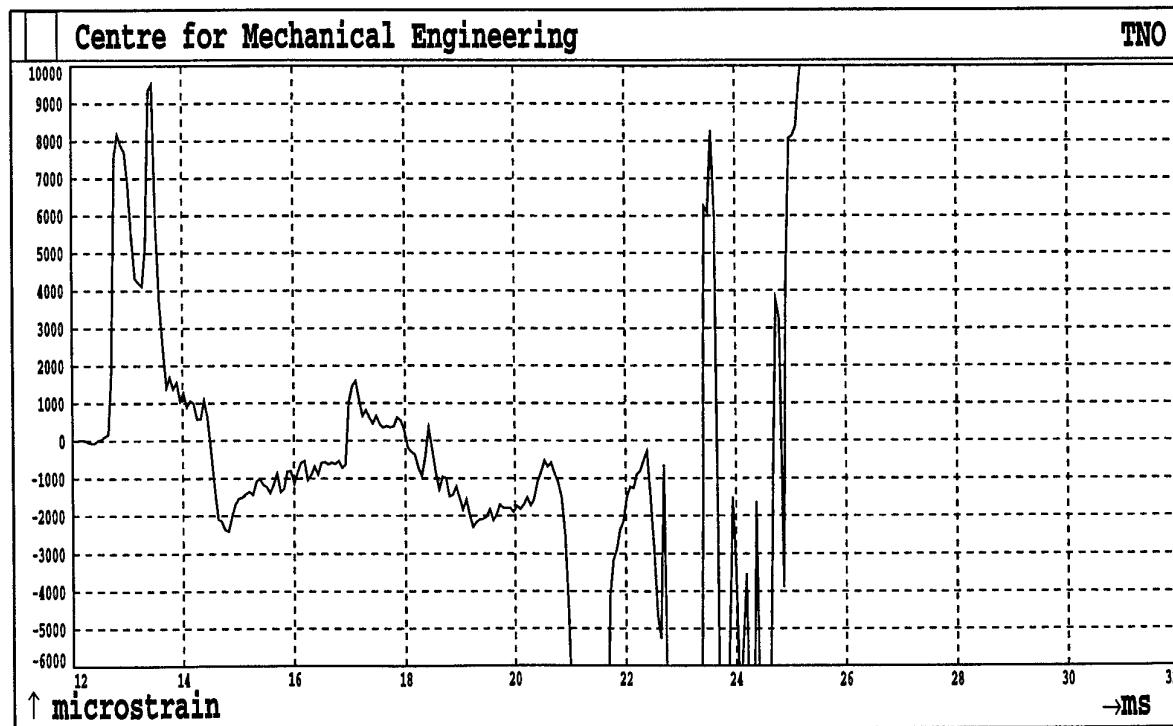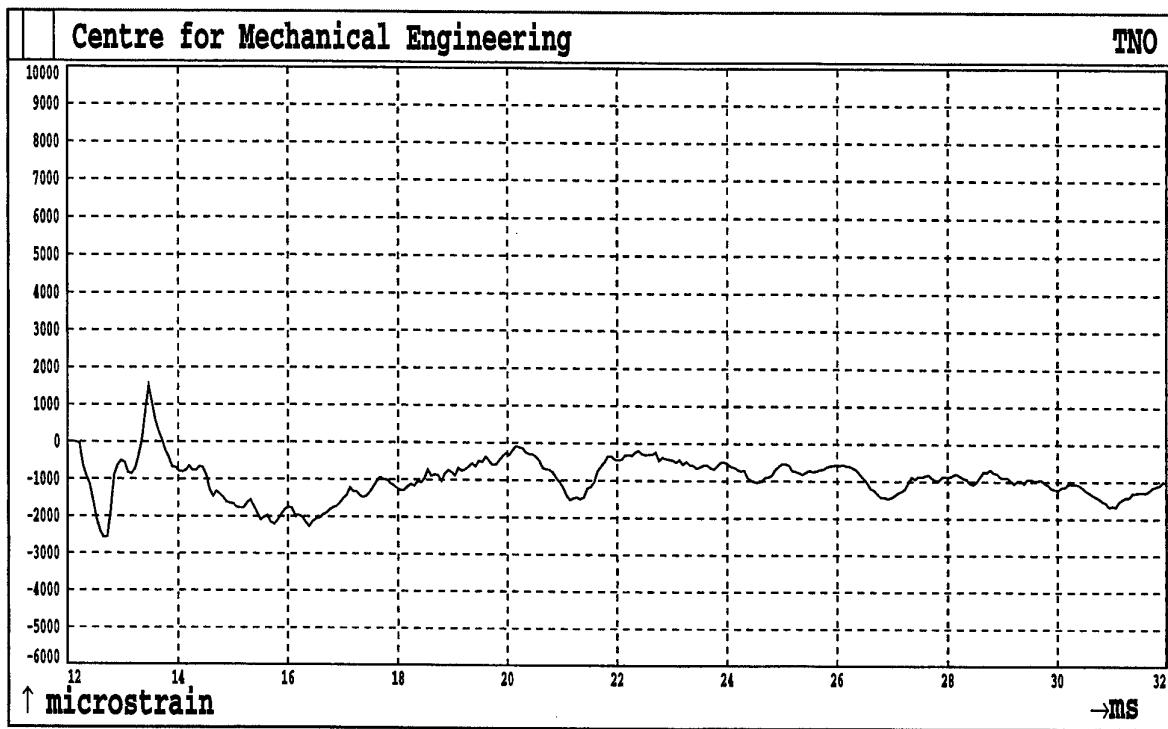
Fig.178. Shot 5   Sensor S7

Fig.179. Shot 5   Sensor S8
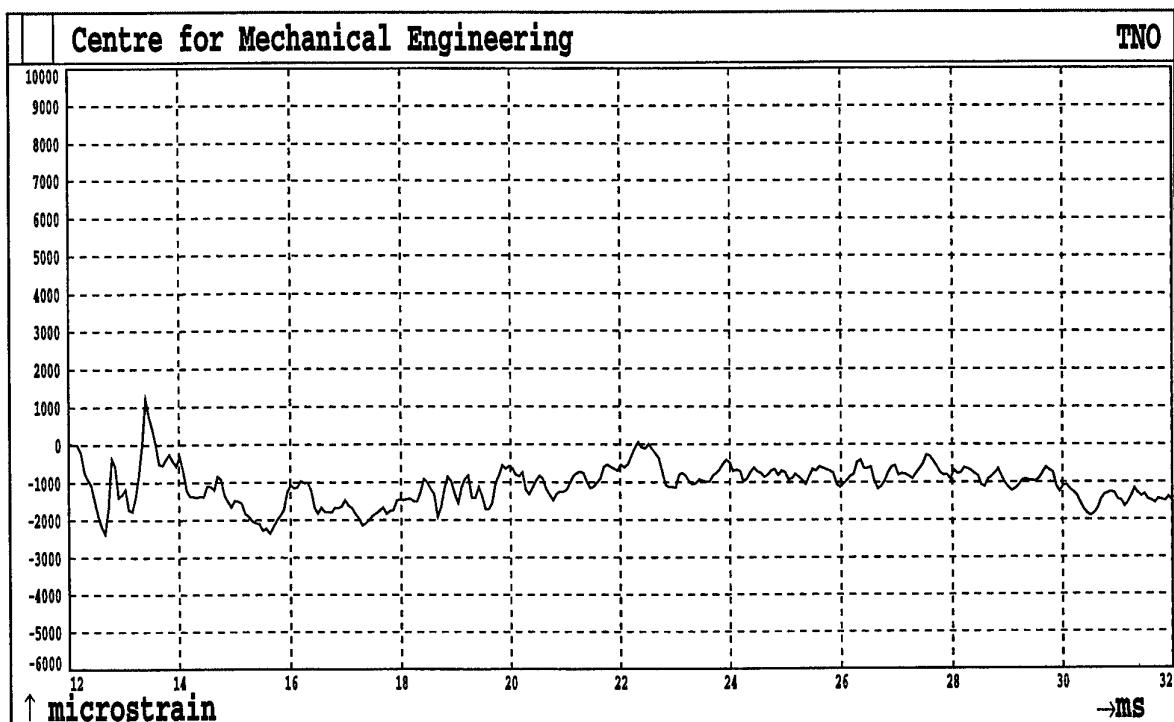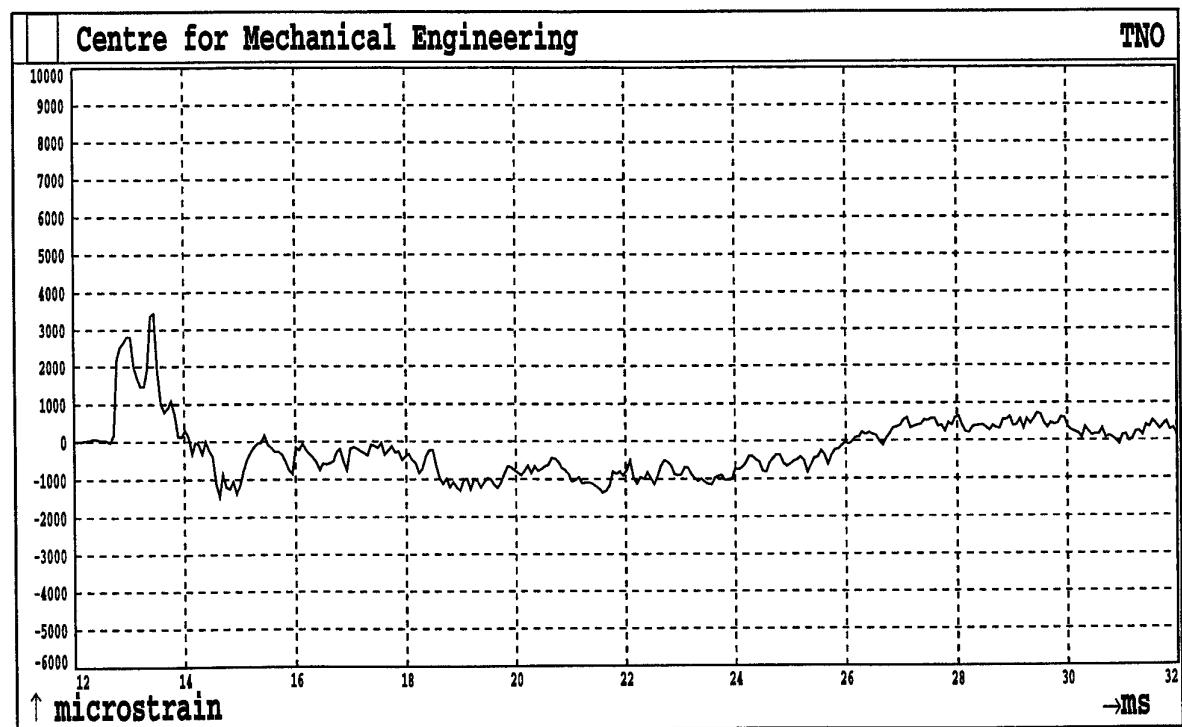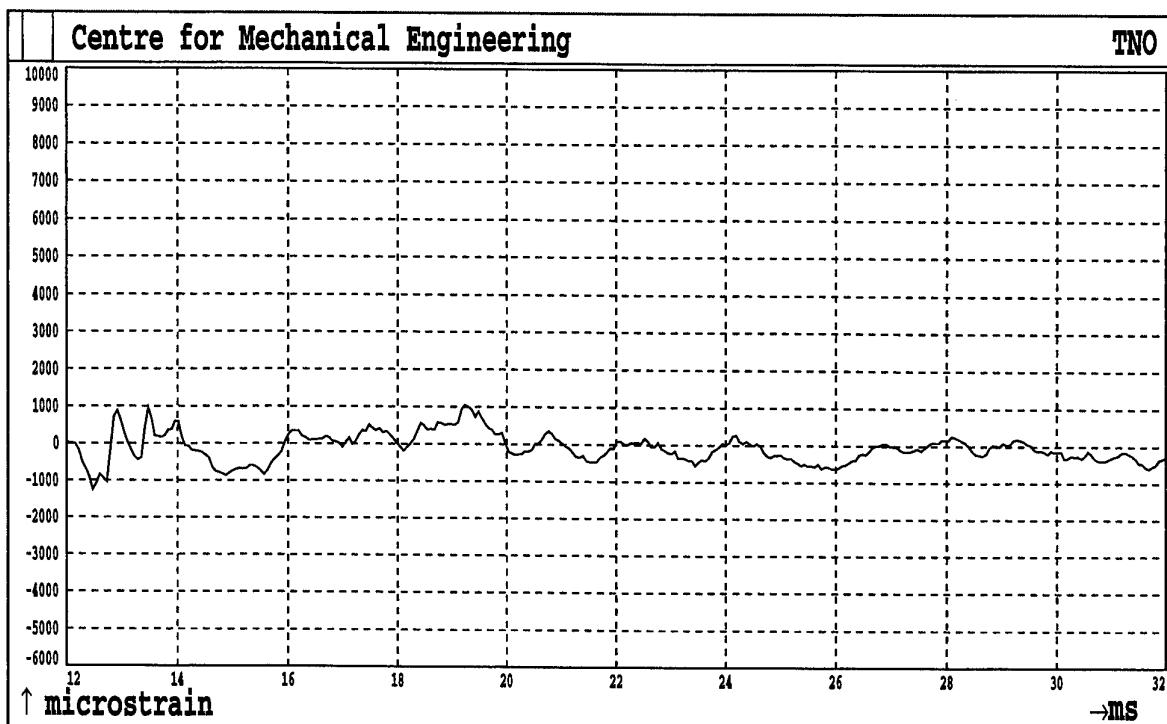
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Fig.180. Shot 5　Sensor S11

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Fig.181. Shot 5　Sensor S12

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Fig.182. Shot 5   Sensor S13

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Fig.183. Shot 5   Sensor S14

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Fig.184. Shot 5   Sensor S15

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Fig.185. Shot 5   Sensor S16

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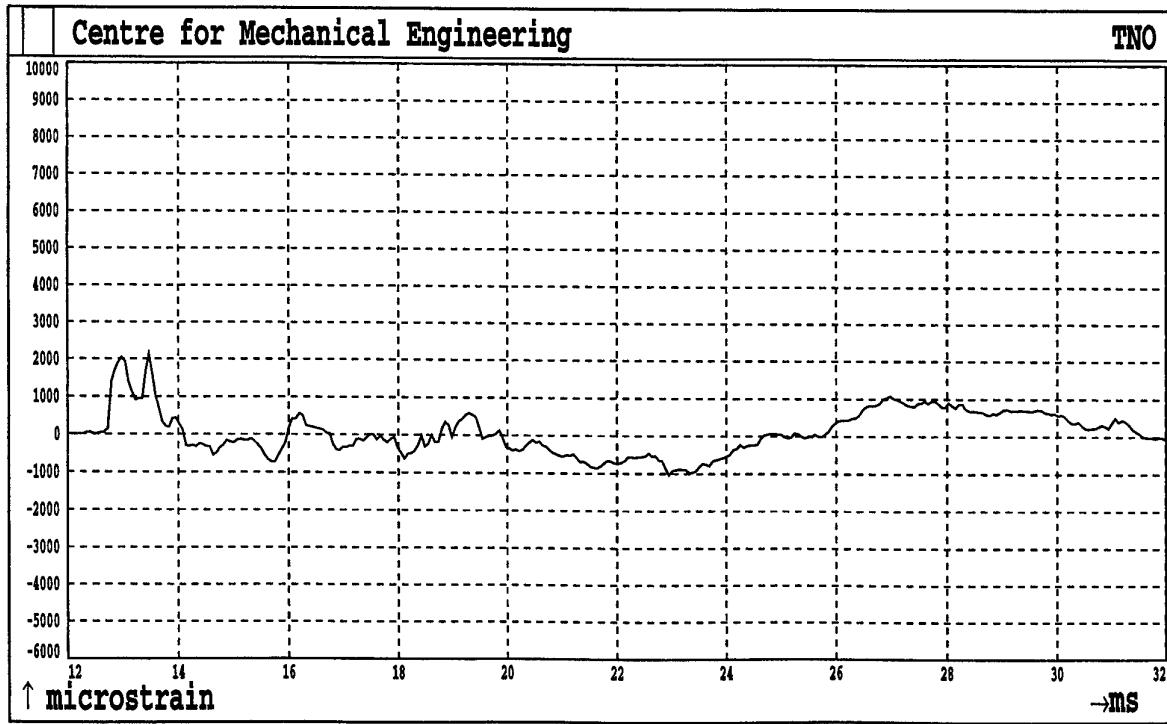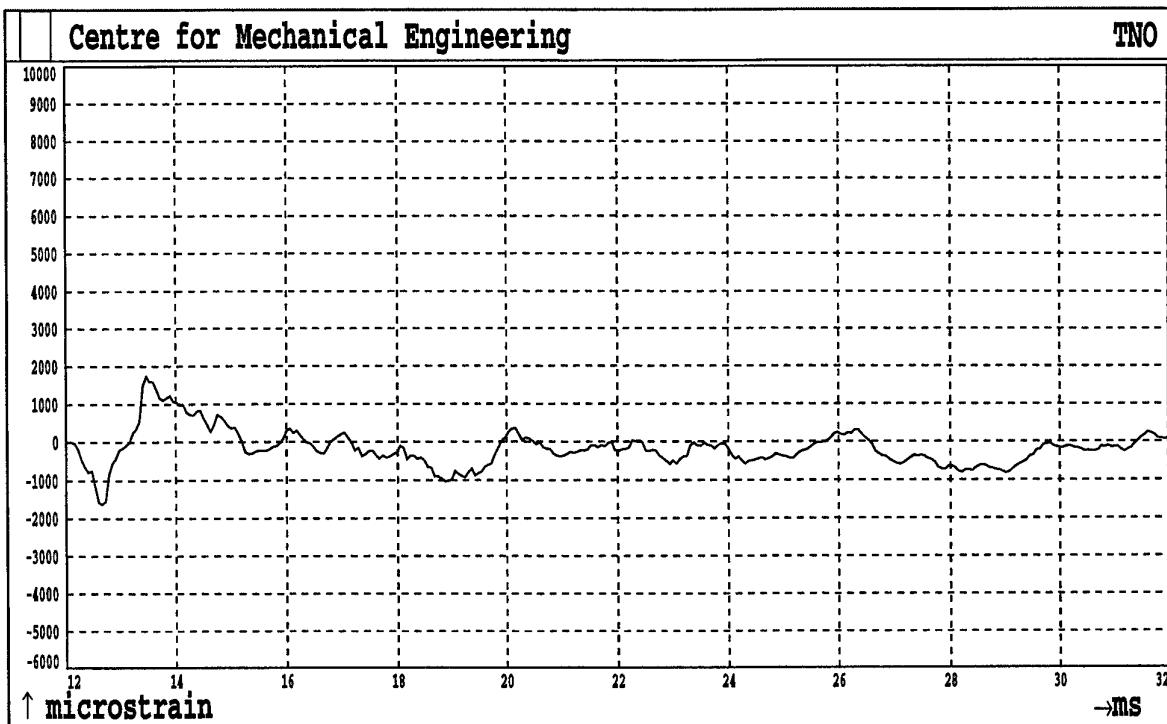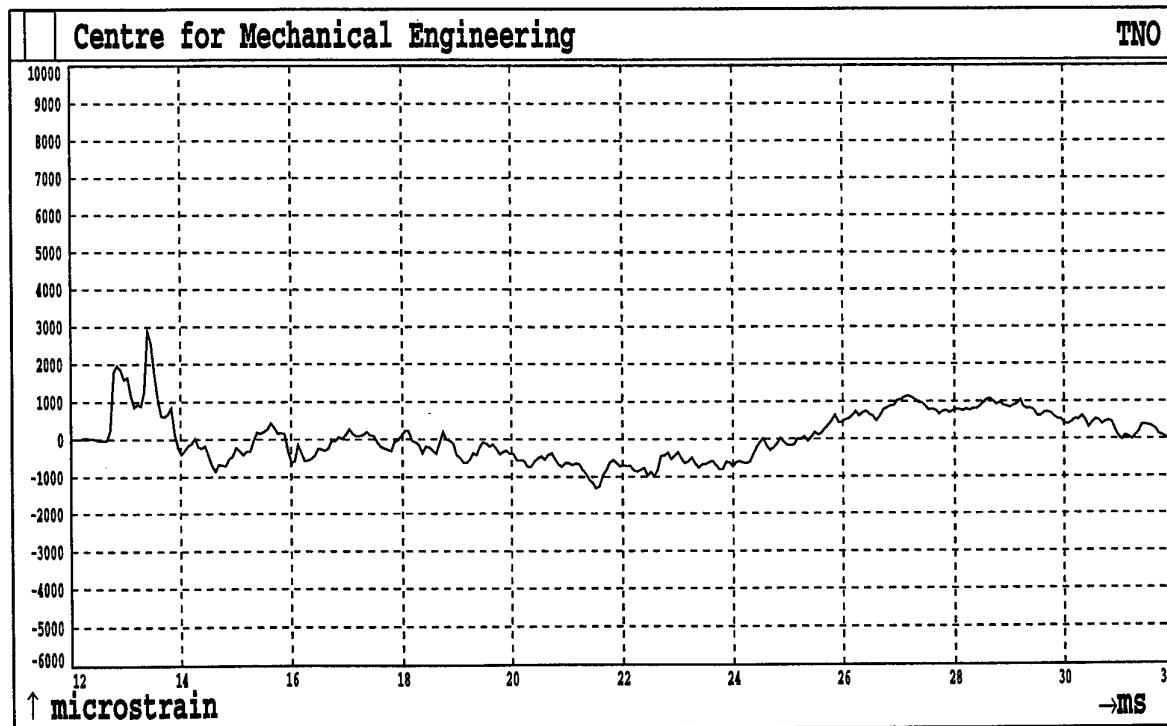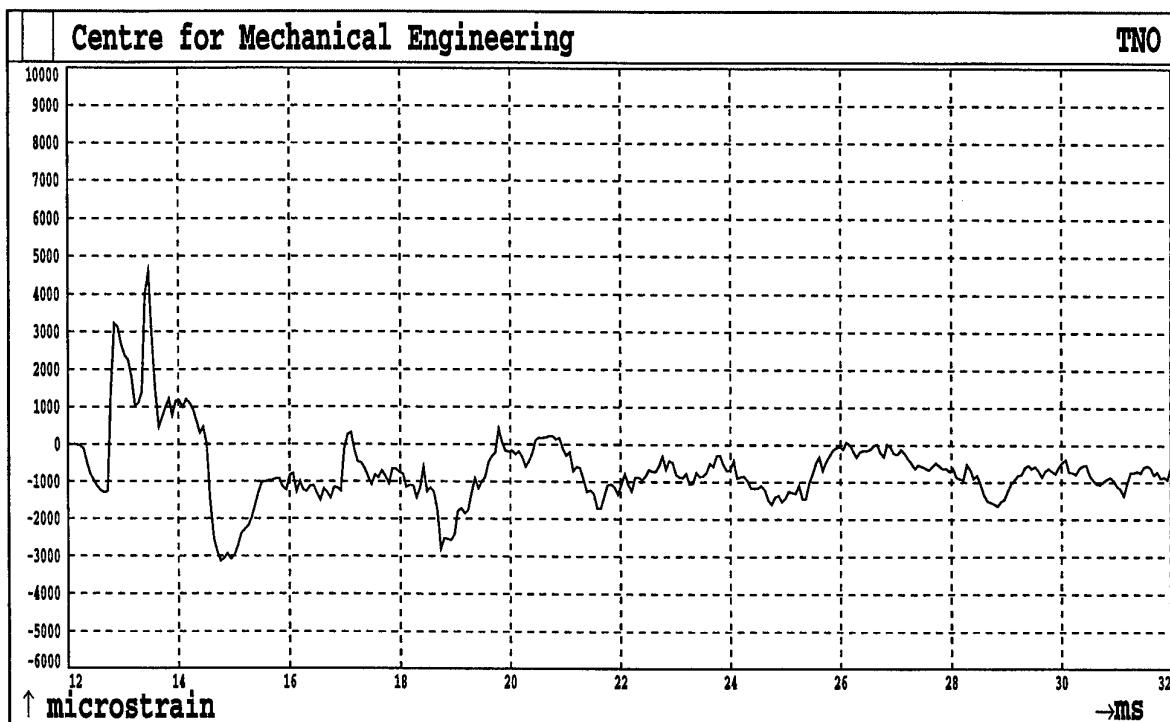
Fig.186. Shot 5   Sensor S17

Fig.187. Shot 5   Sensor S18

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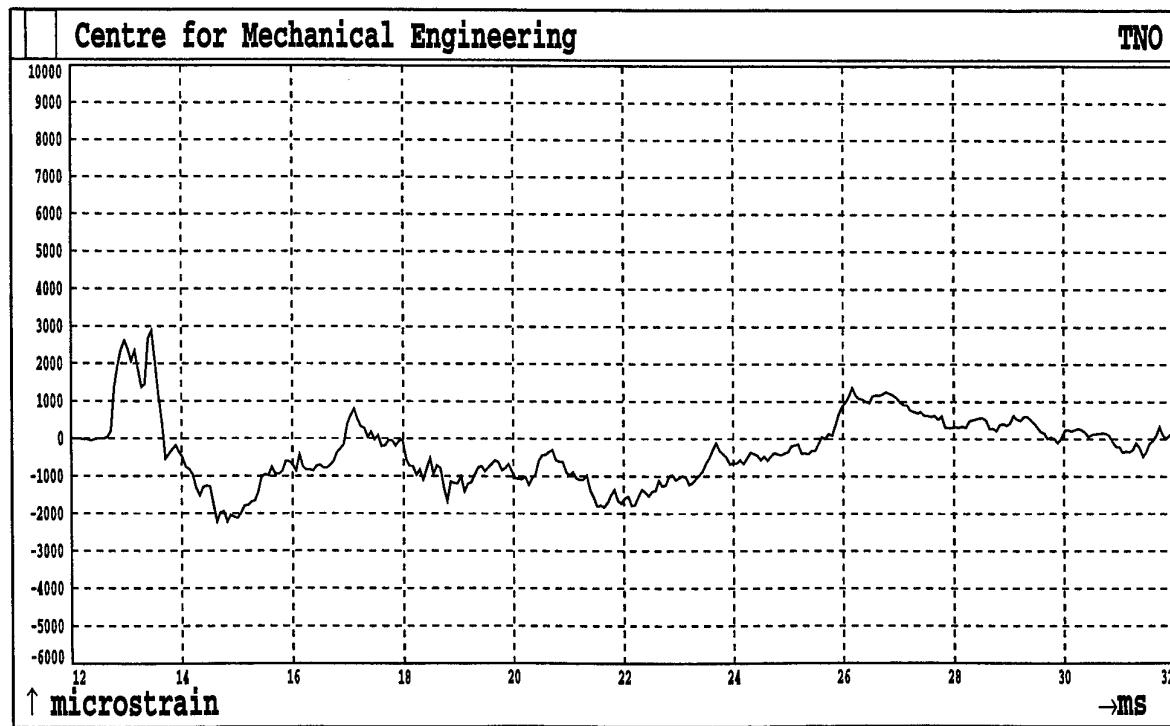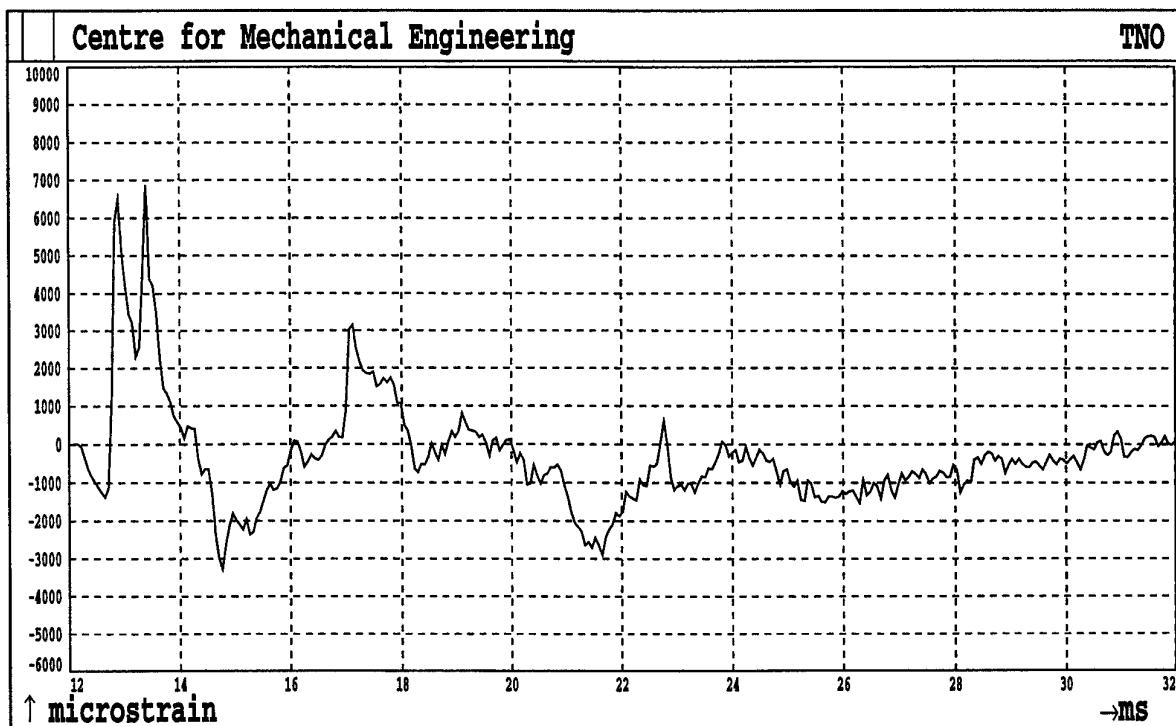
Fig.188. Shot 5   Sensor S19

Fig.189. Shot 5   Sensor S20

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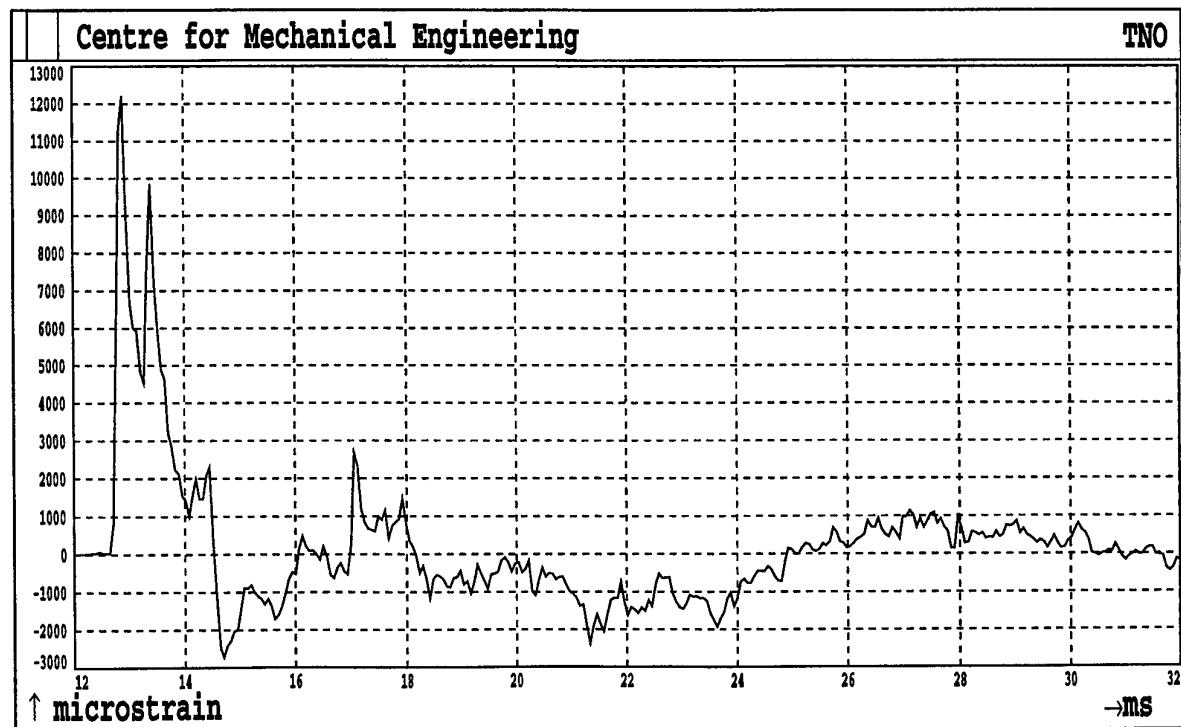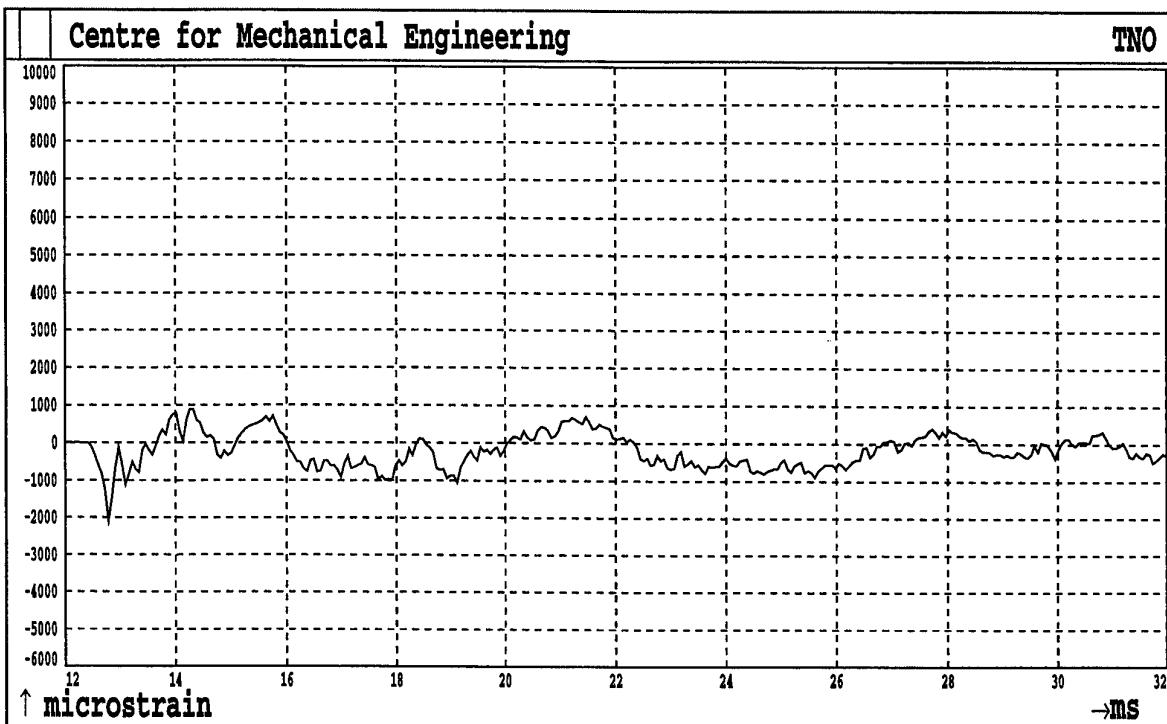
Fig.190. Shot 5 Sensor S21

Fig.191. Shot 5 Sensor S22

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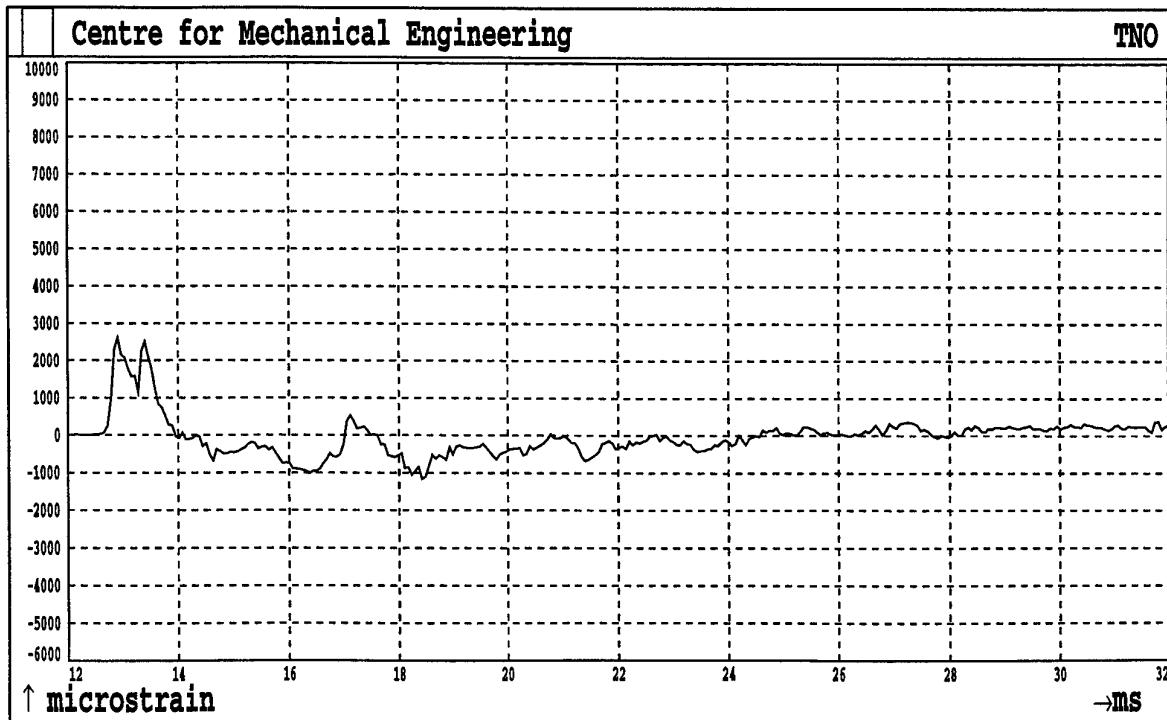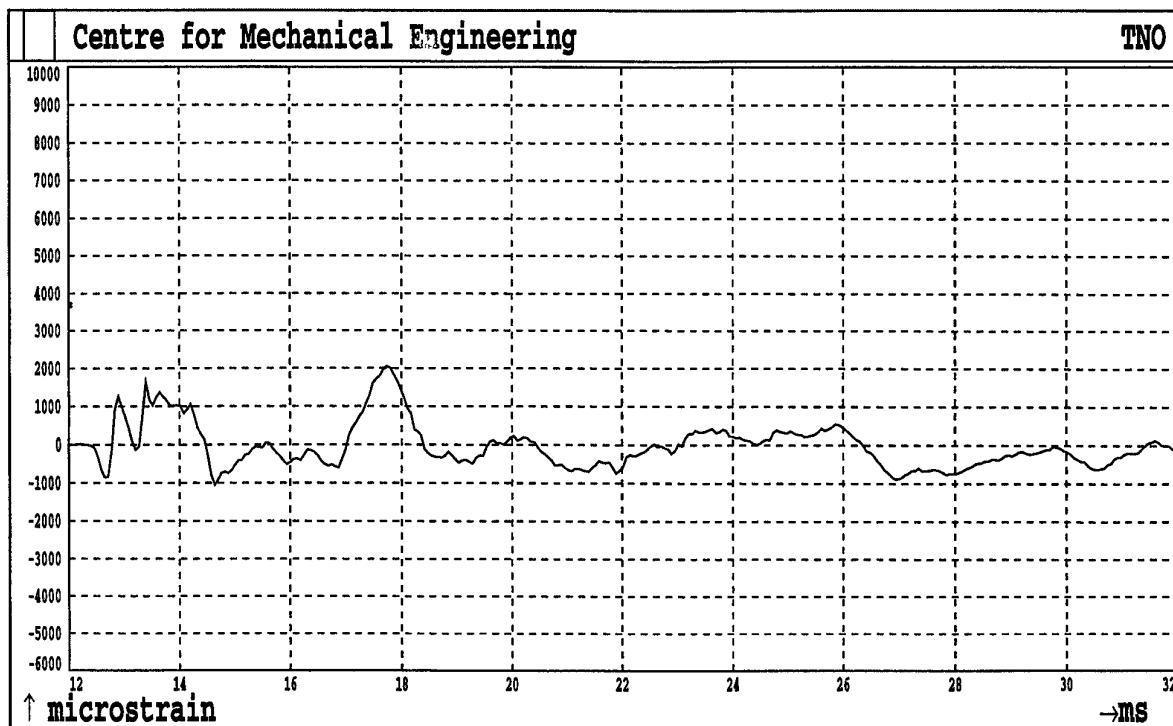
Fig.192. Shot 5 Sensor S23

Fig.193. Shot 5 Sensor S24

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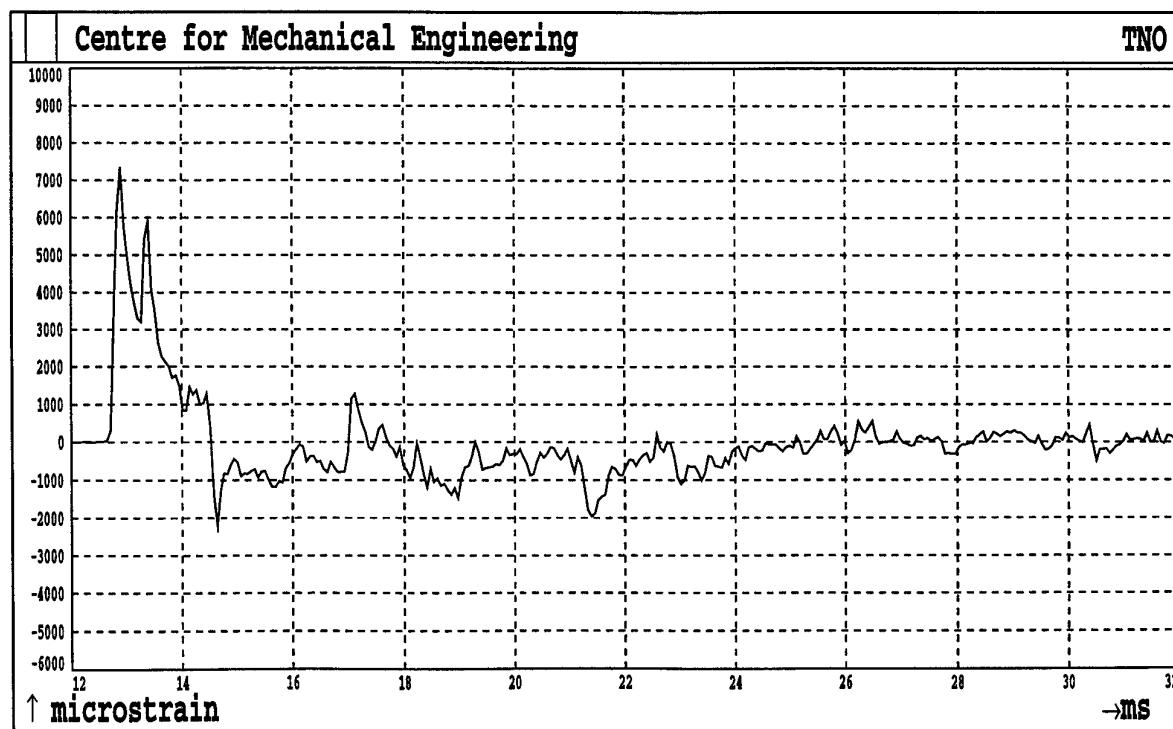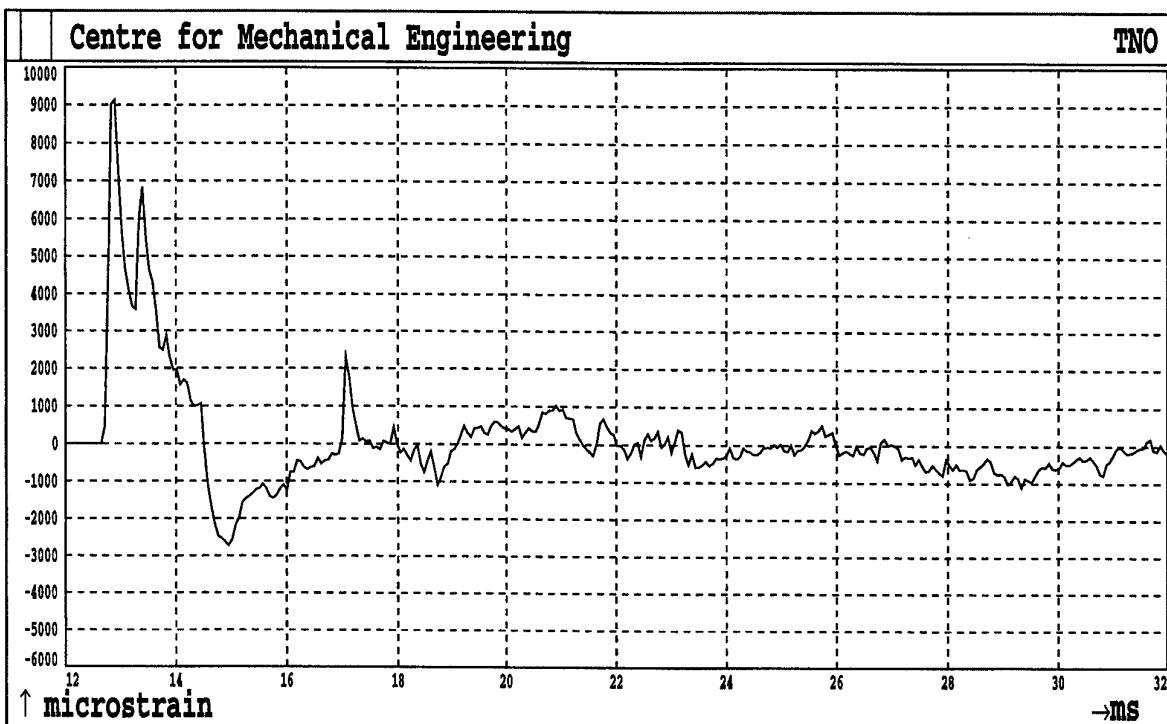
Fig.194. Shot 5 Sensor S25

Fig.195. Shot 5 Sensor S26

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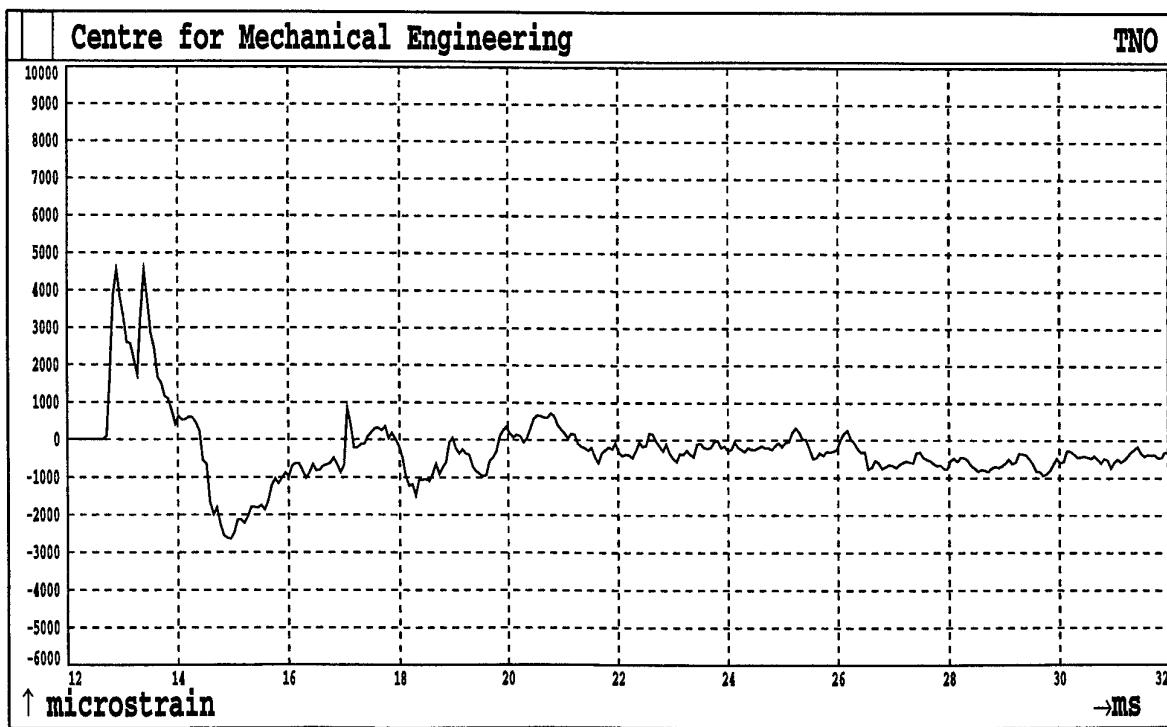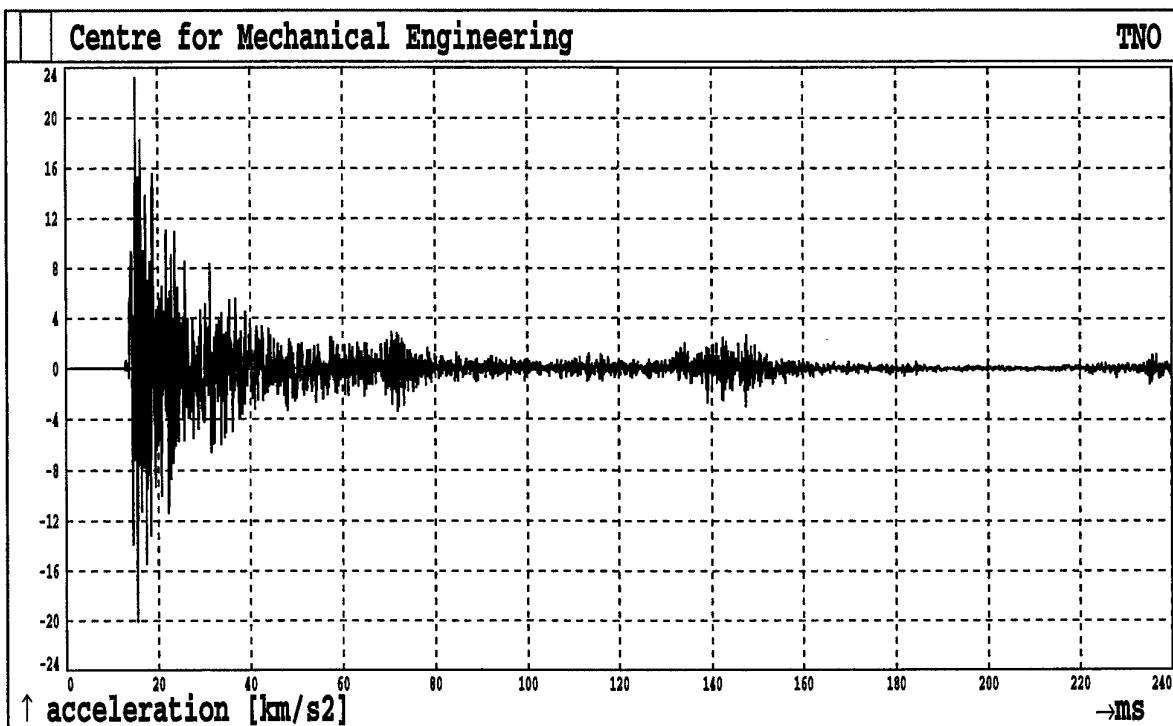
Fig.196. Shot 5 Sensor A2

Fig.197. Shot 5 Sensor A5

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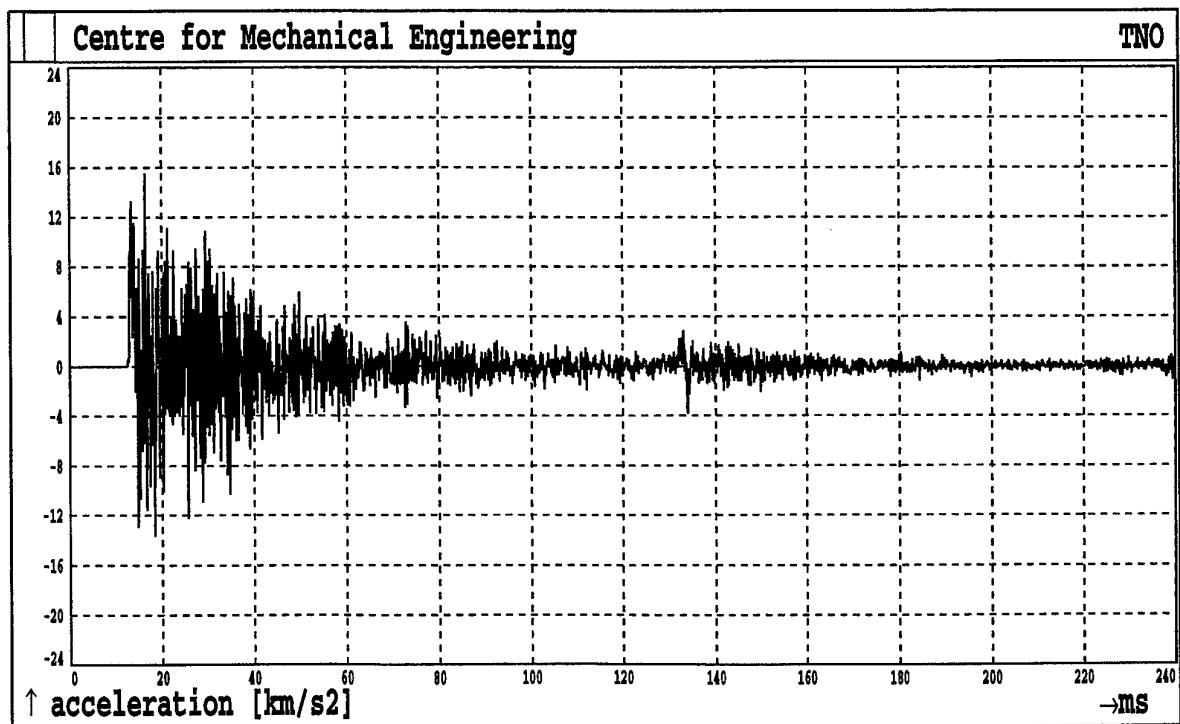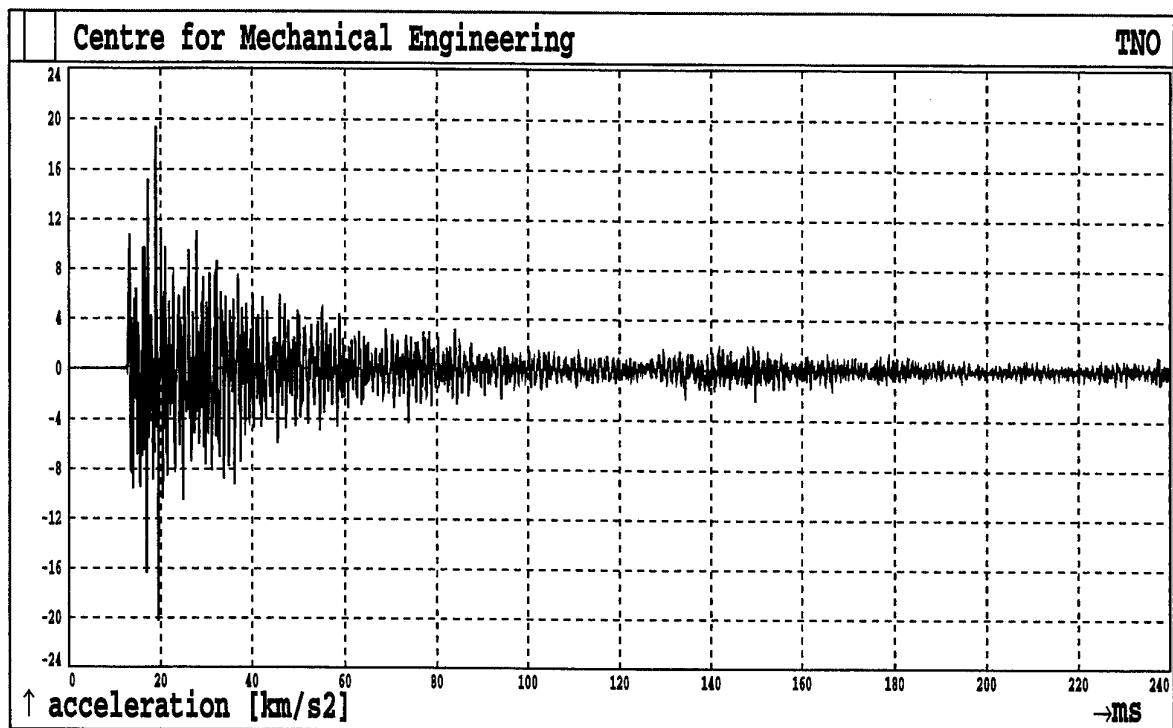
Fig.198. Shot 5   Sensor A6

Fig.199. Shot 5   Sensor A8

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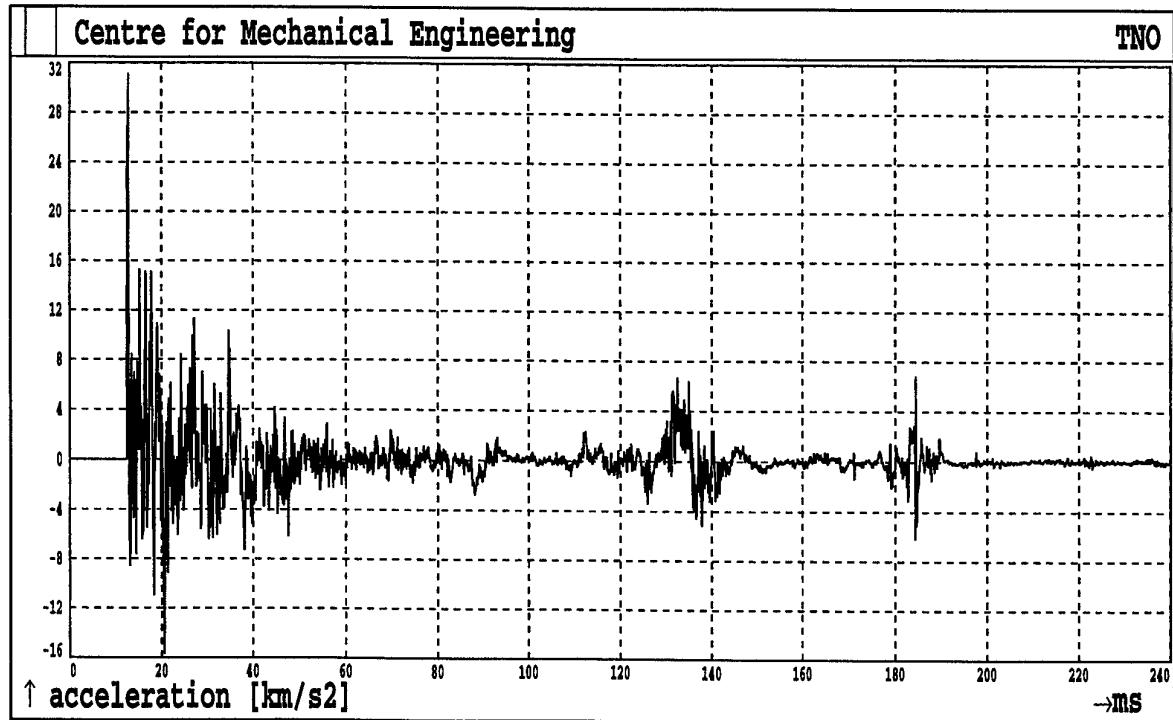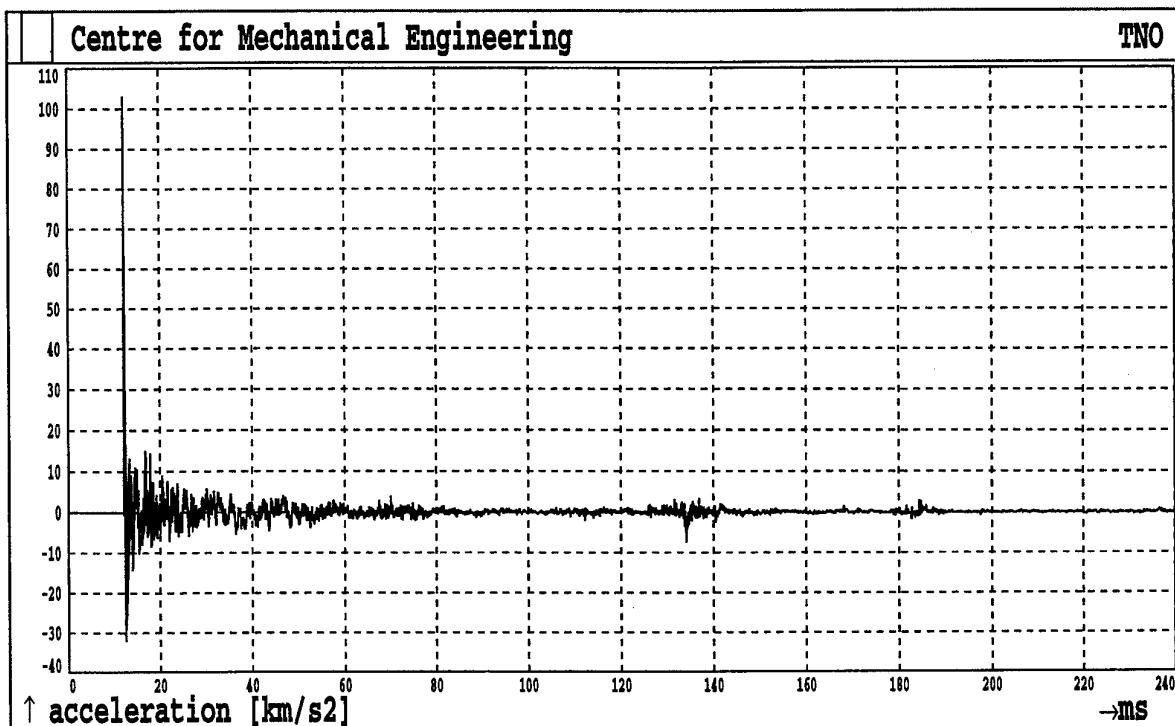
Fig.200. Shot 5   Sensor A9

Fig.201. Shot 5   Sensor A10

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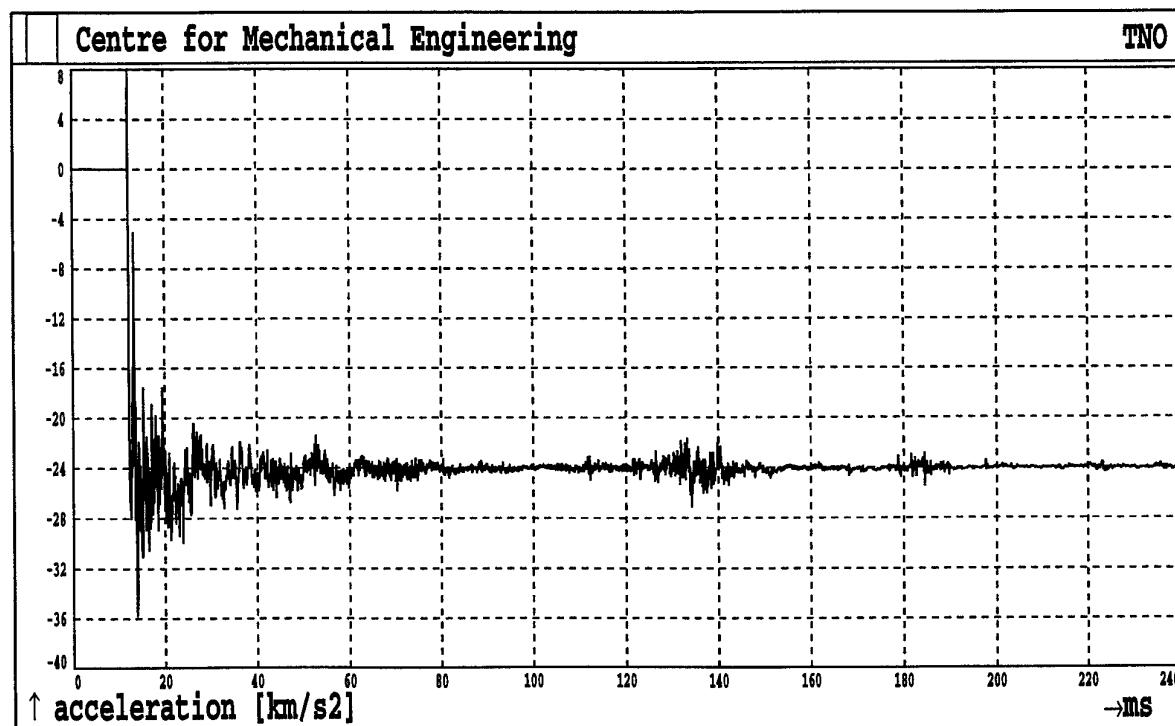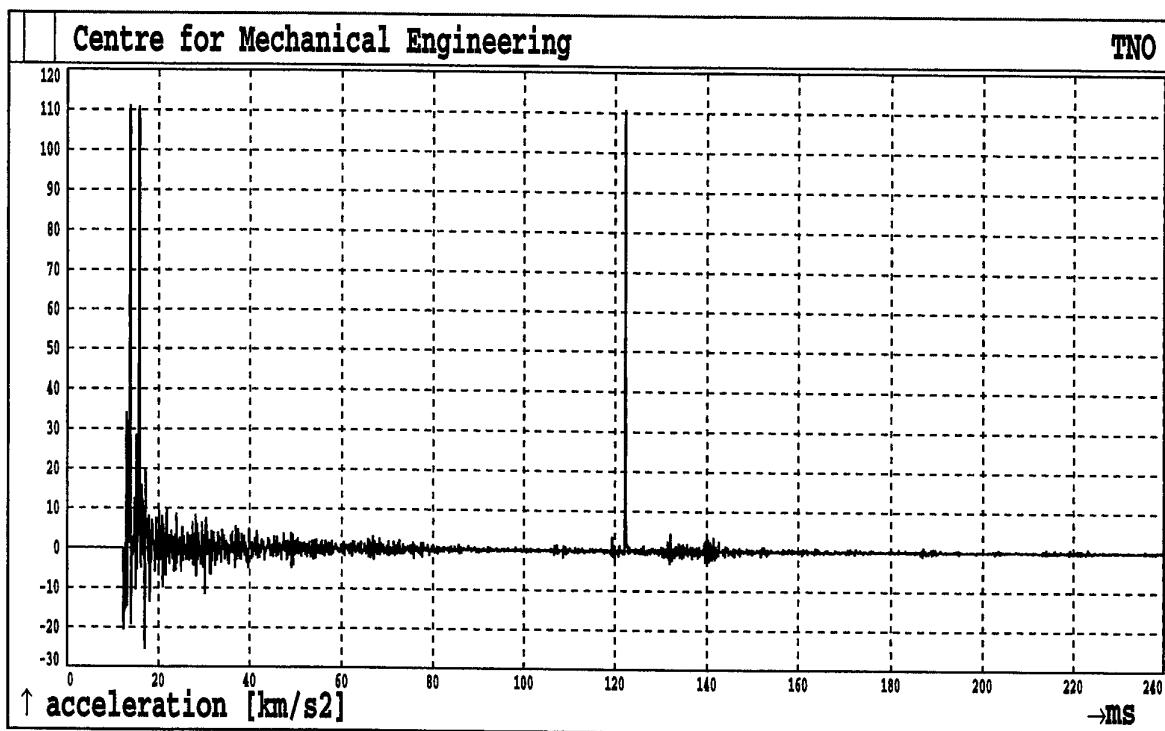
Fig.202. Shot 5   Sensor A11

Fig.203. Shot 5   Sensor A12

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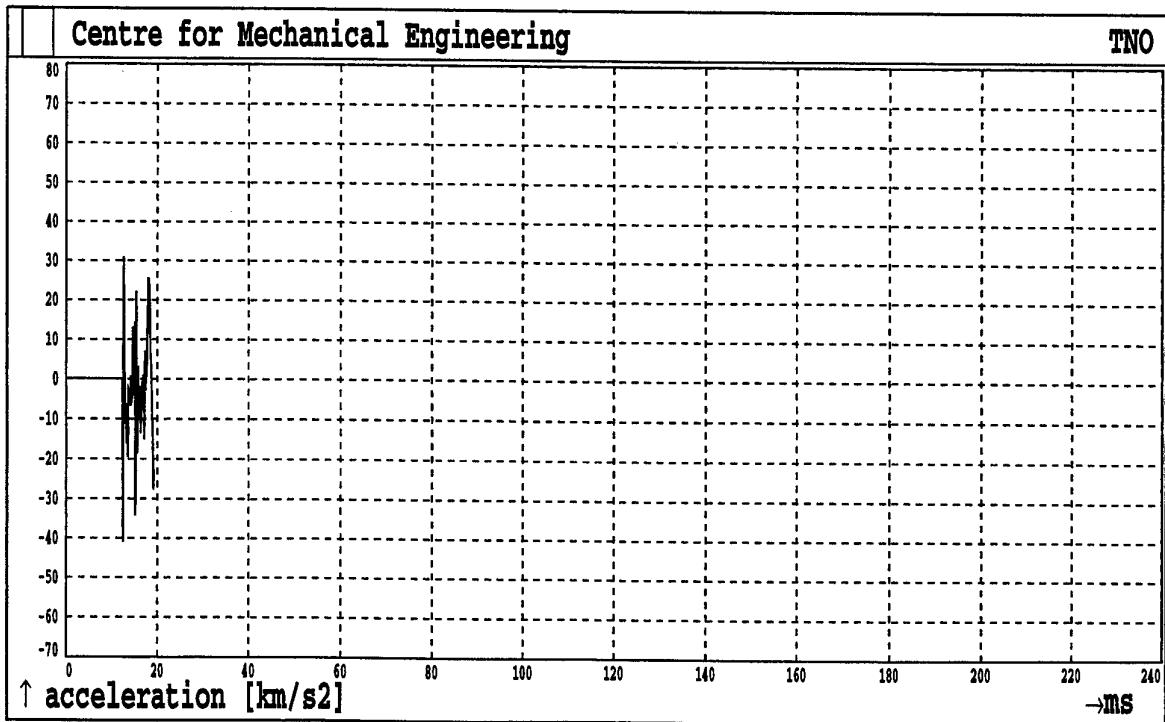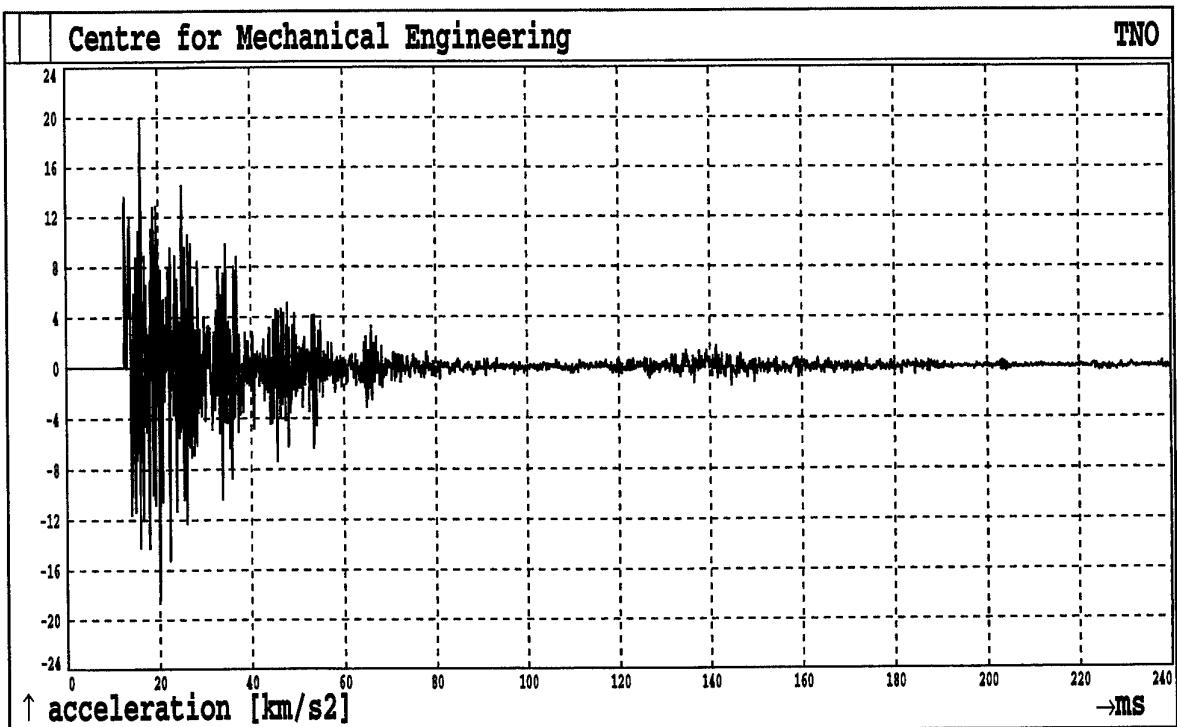
Fig.204. Shot 5   Sensor A13

Fig.205. Shot 5   Sensor A14

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↑ acceleration [km/s2]   →ms

Fig.206. Shot 5   Sensor A15

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↑ acceleration [km/s2]   →ms

Fig.207. Shot 5   Sensor A16

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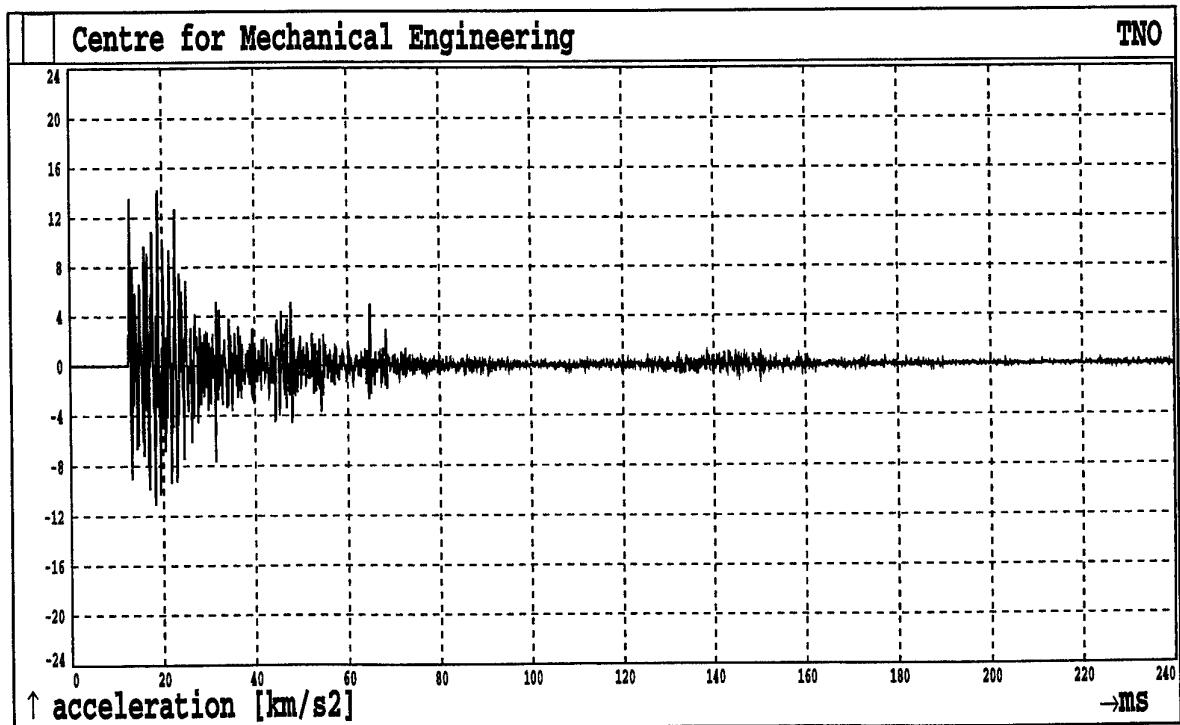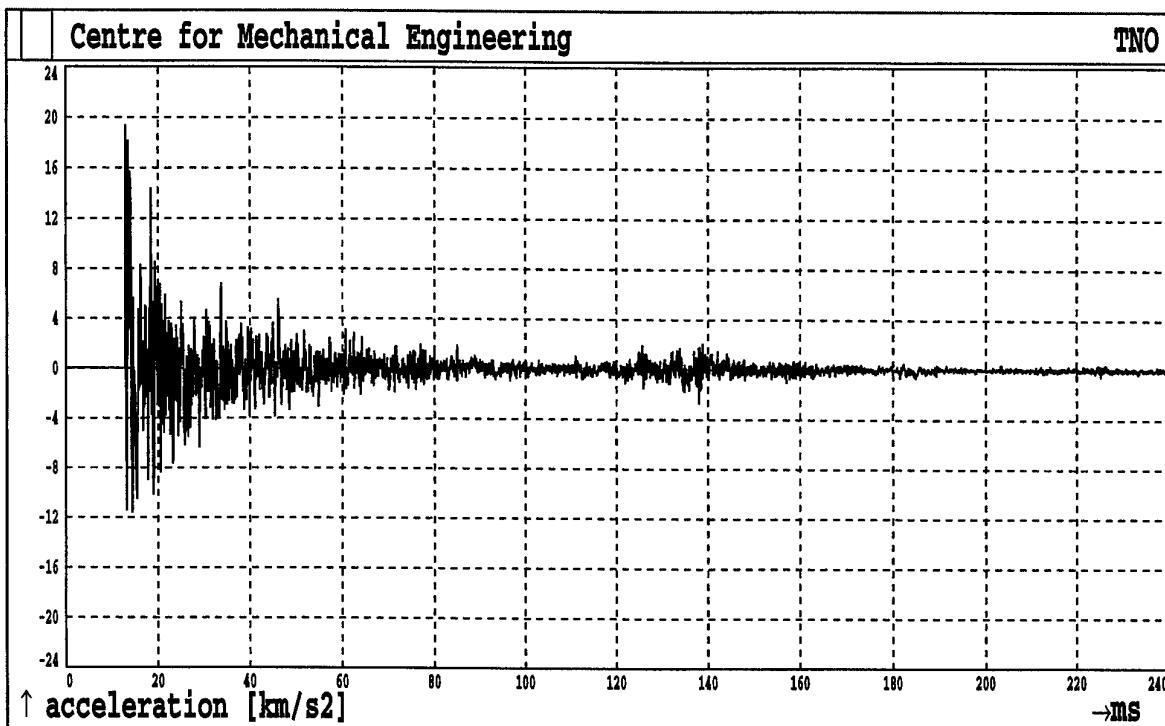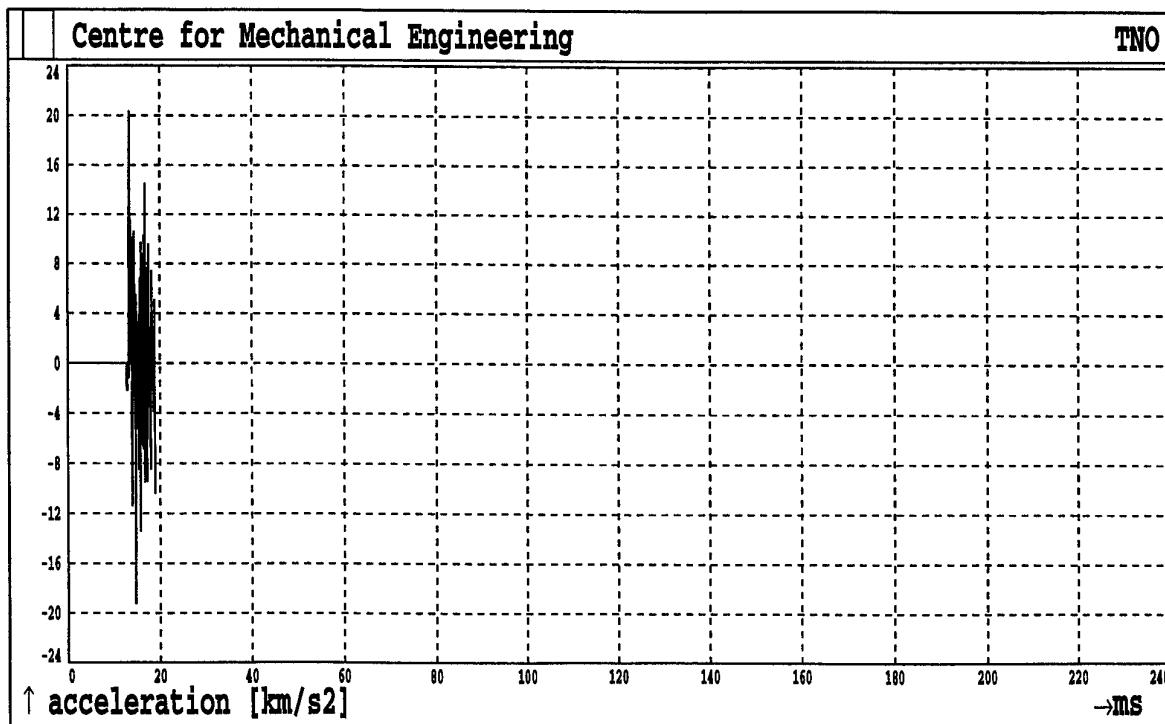
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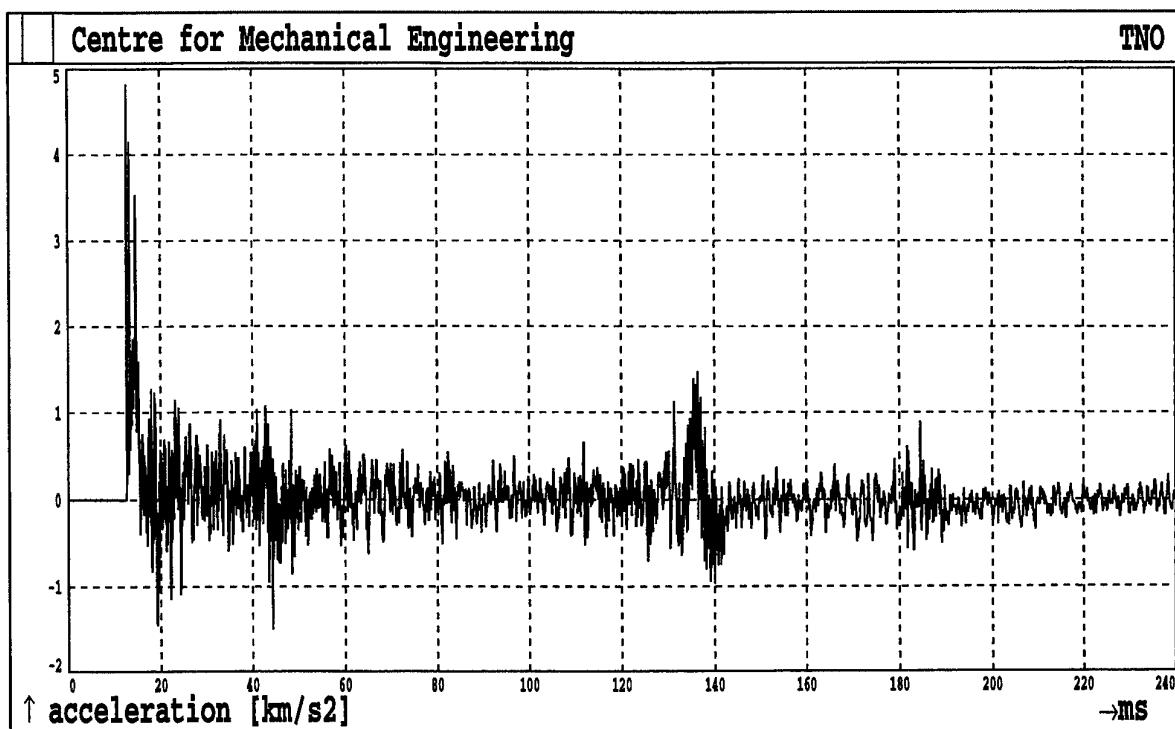
Fig.208. Shot 5 Sensor A17
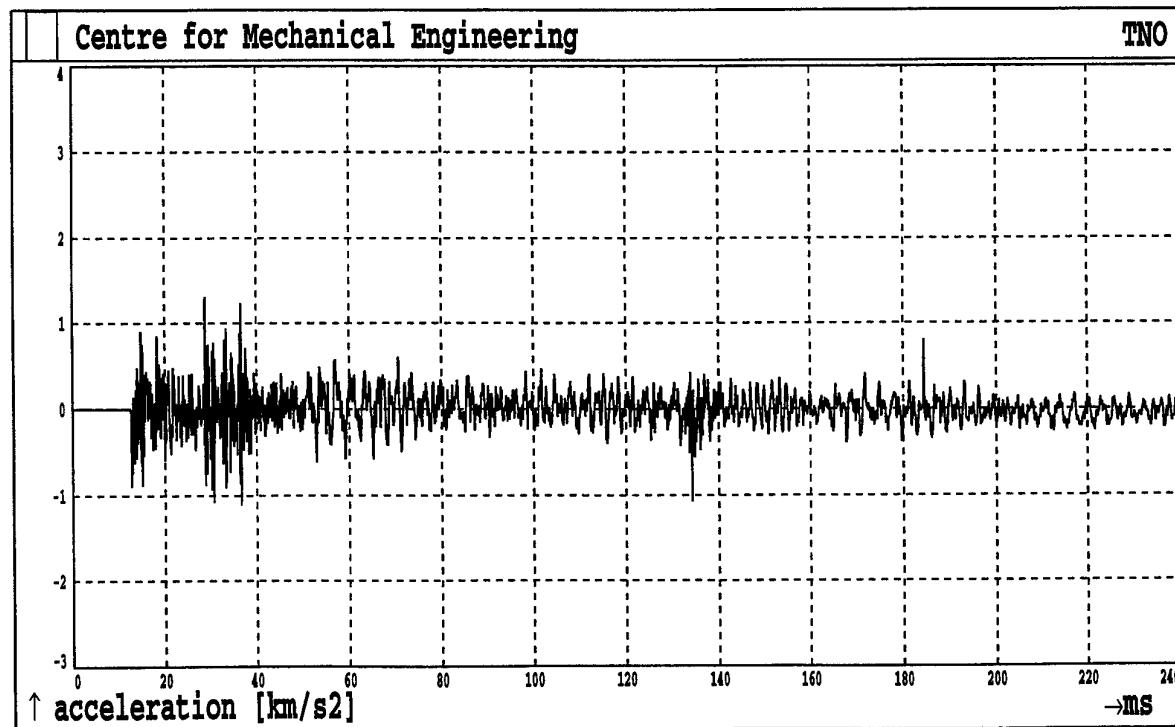
Fig.209. Shot 5 Sensor A22
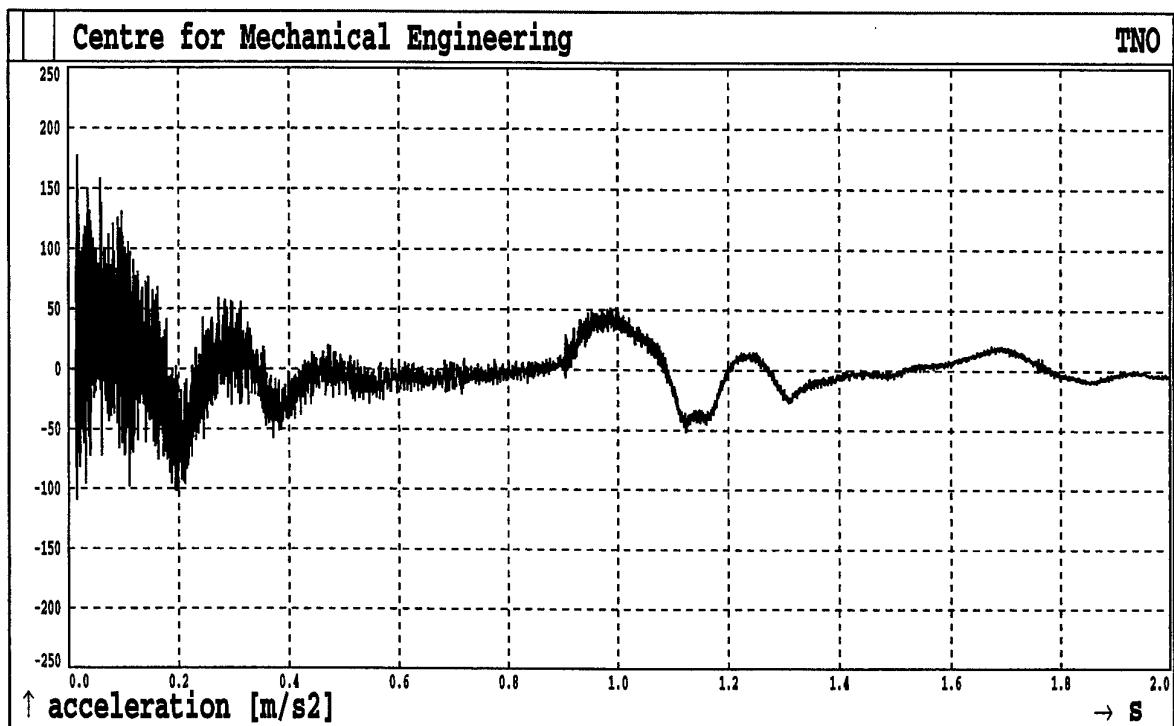
Fig.210. Shot 5   Sensor A25
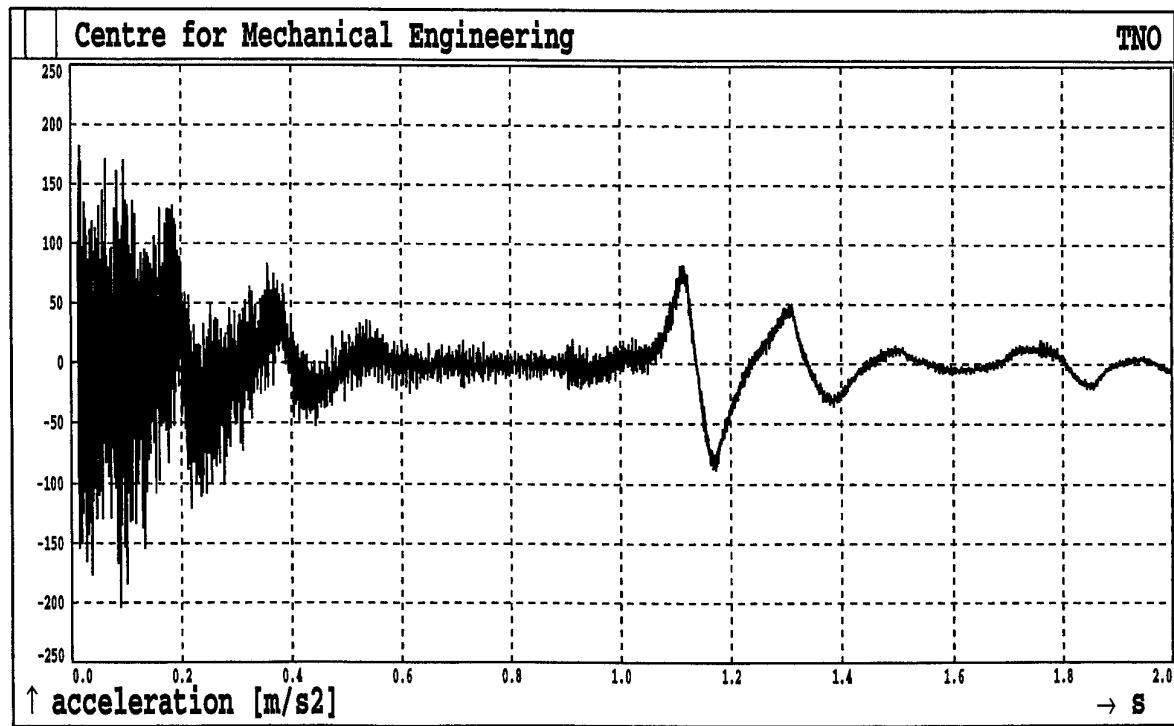
Fig.211. Shot 5   Sensor A26
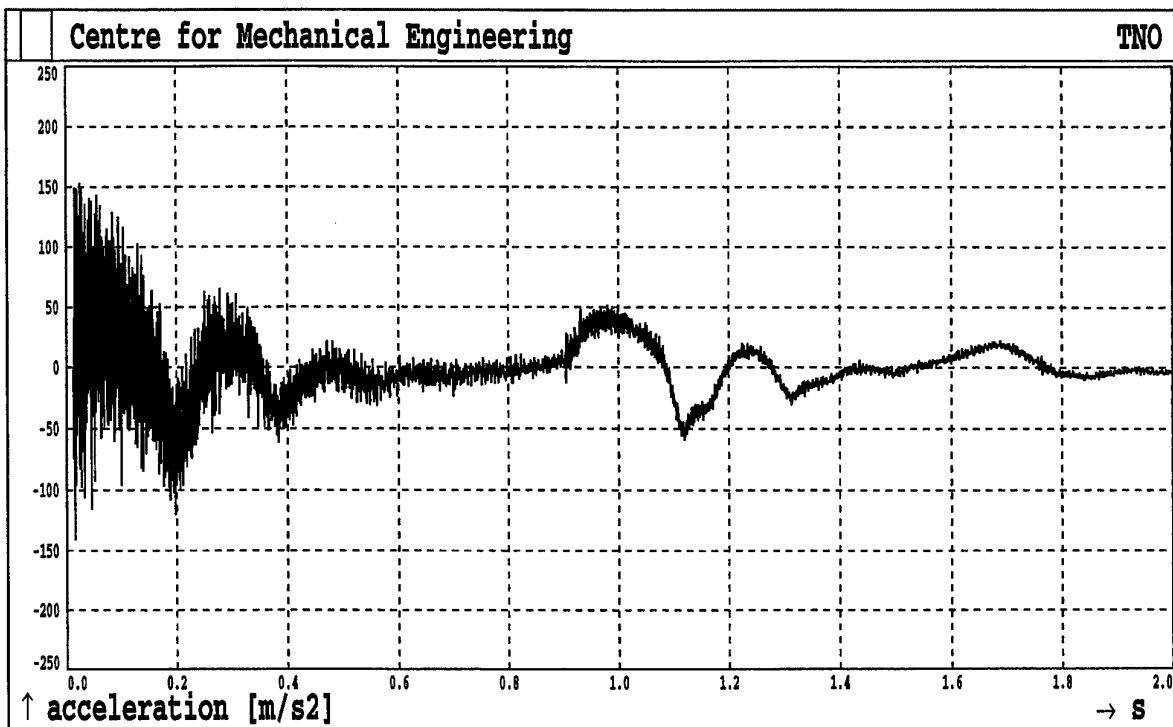
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Fig.212. Shot 5   Sensor A27

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Fig.213. Shot 5   Sensor A28

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↑ velocity [m/s] →ms

Fig.214. Shot 5   Sensor A2

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↑ velocity [m/s] →ms

Fig.215. Shot 5   Sensor A5

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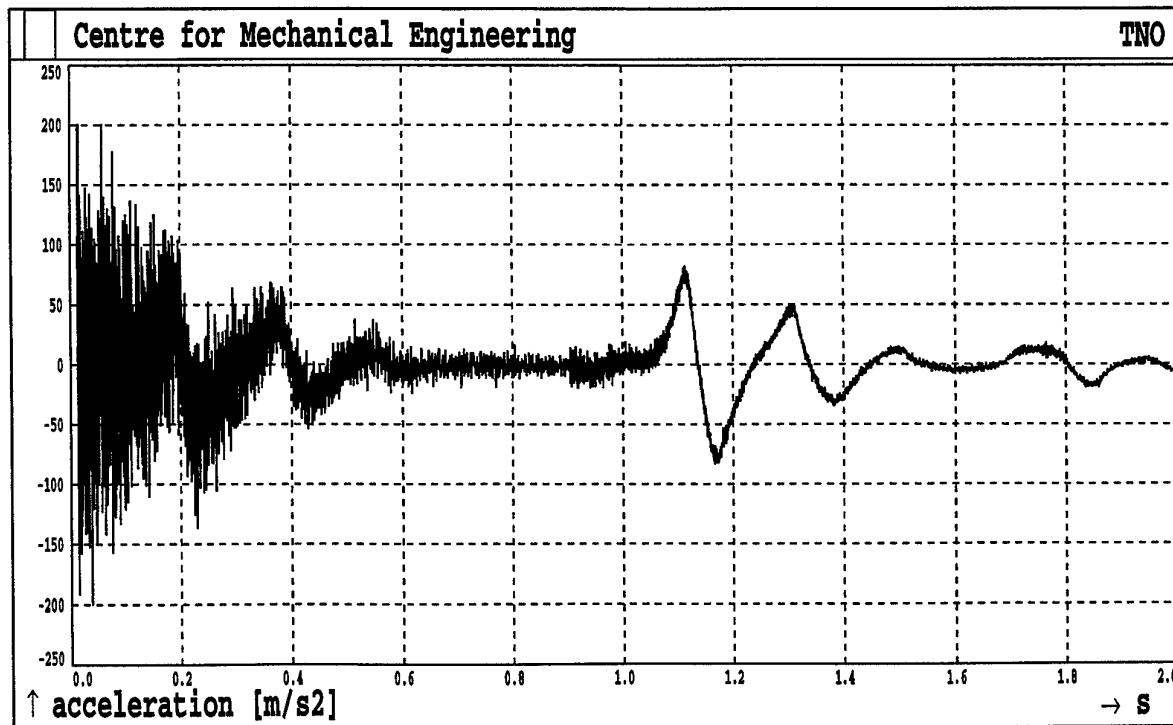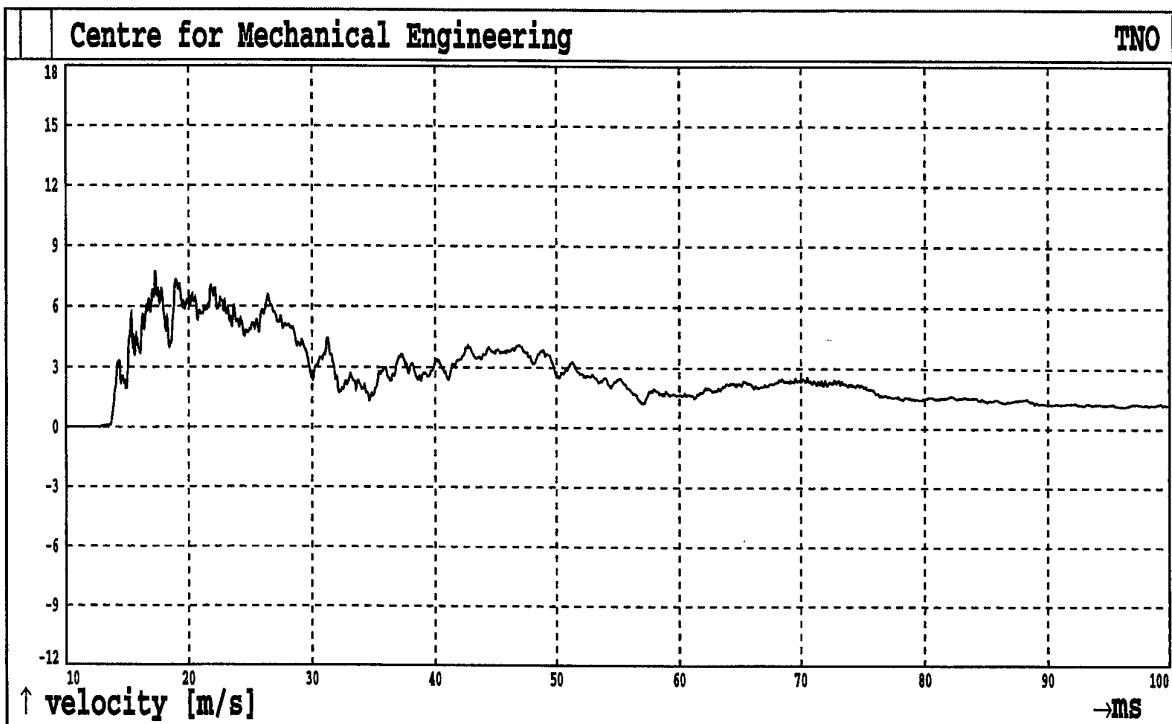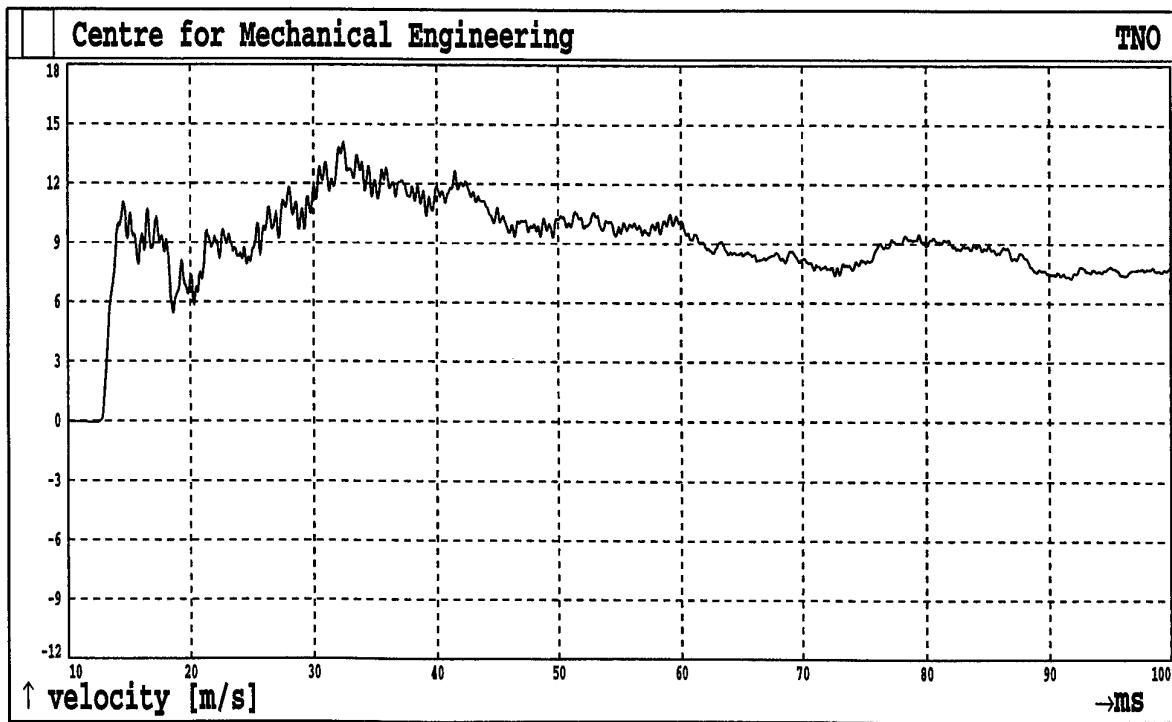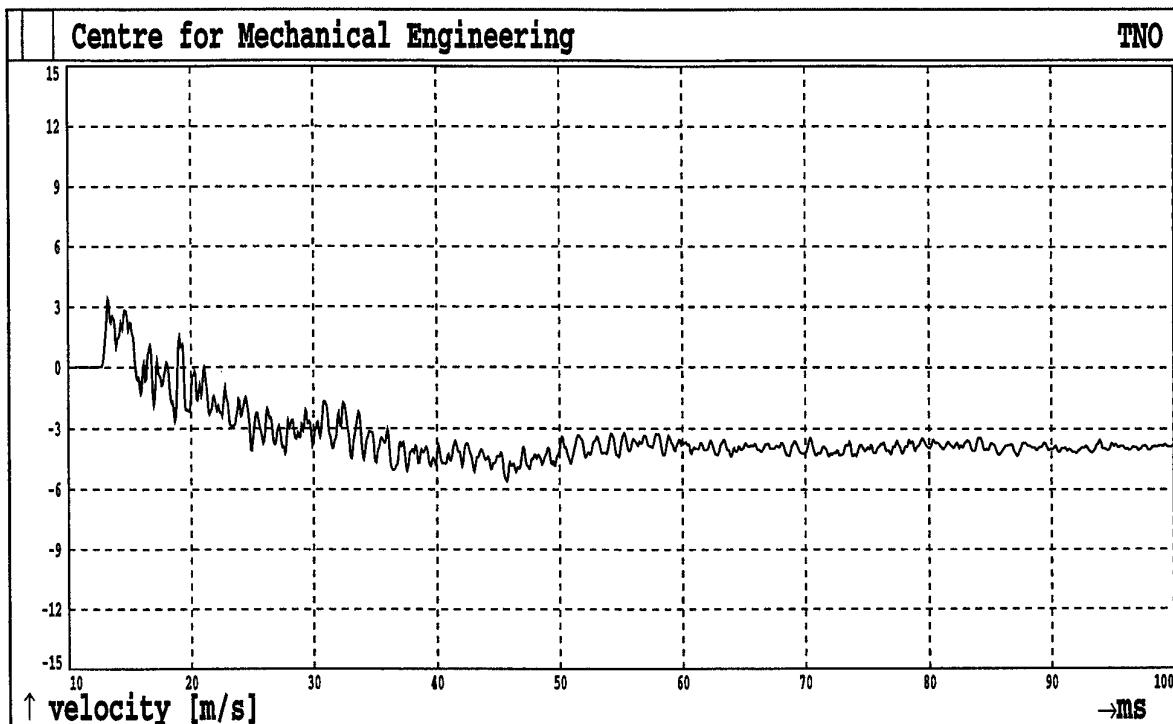
Fig.216. Shot 5 Sensor A6

Fig.217. Shot 5 Sensor A8

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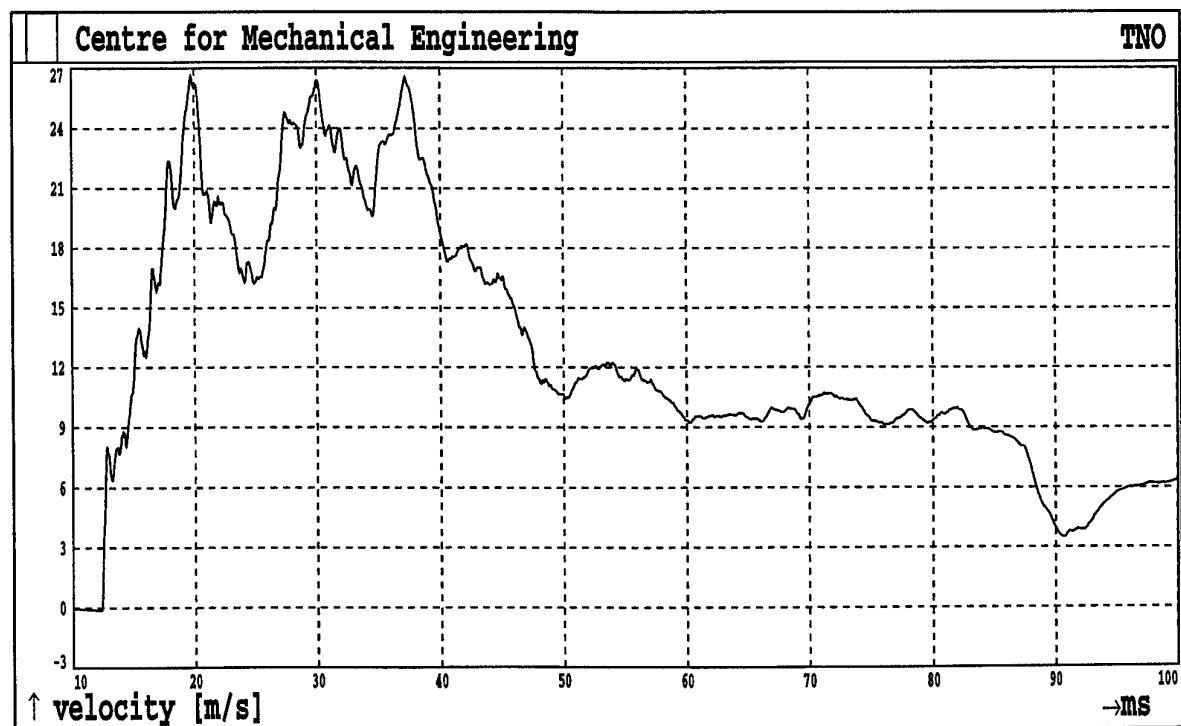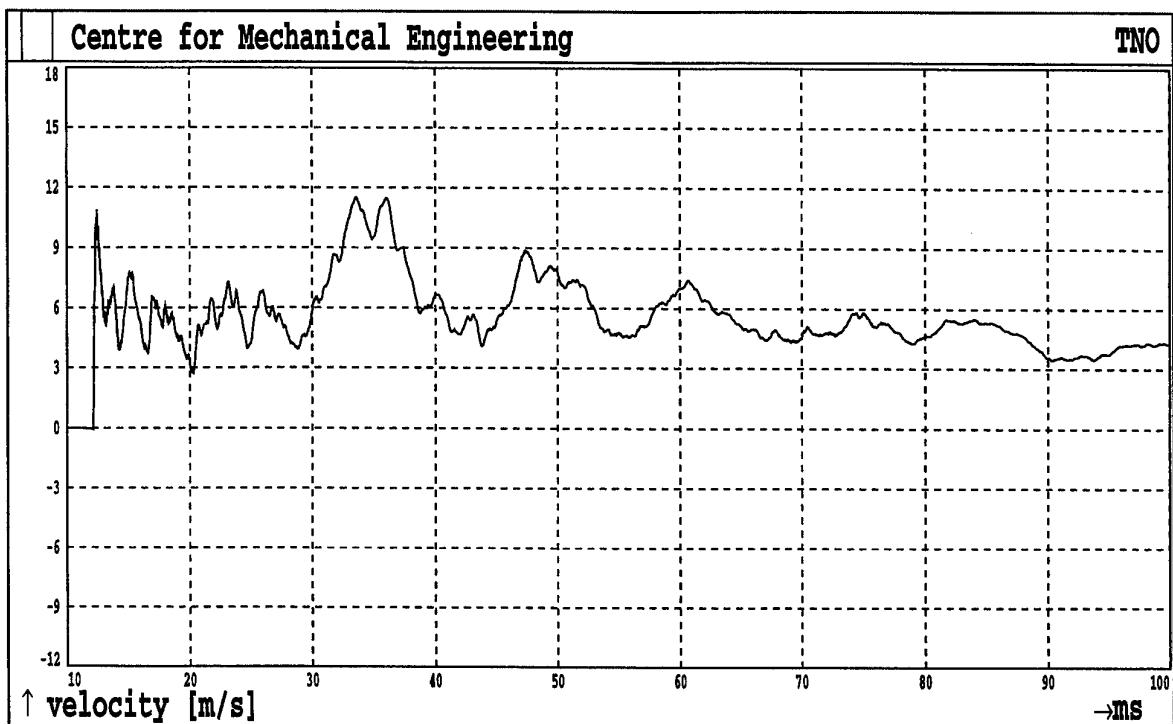
Fig.218. Shot 5   Sensor A9

Fig.219. Shot 5   Sensor A12

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↑ velocity [m/s]   →ms

Fig.220. Shot 5   Sensor A13

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↑ velocity [m/s]   →ms

Fig.221. Shot 5   Sensor A14

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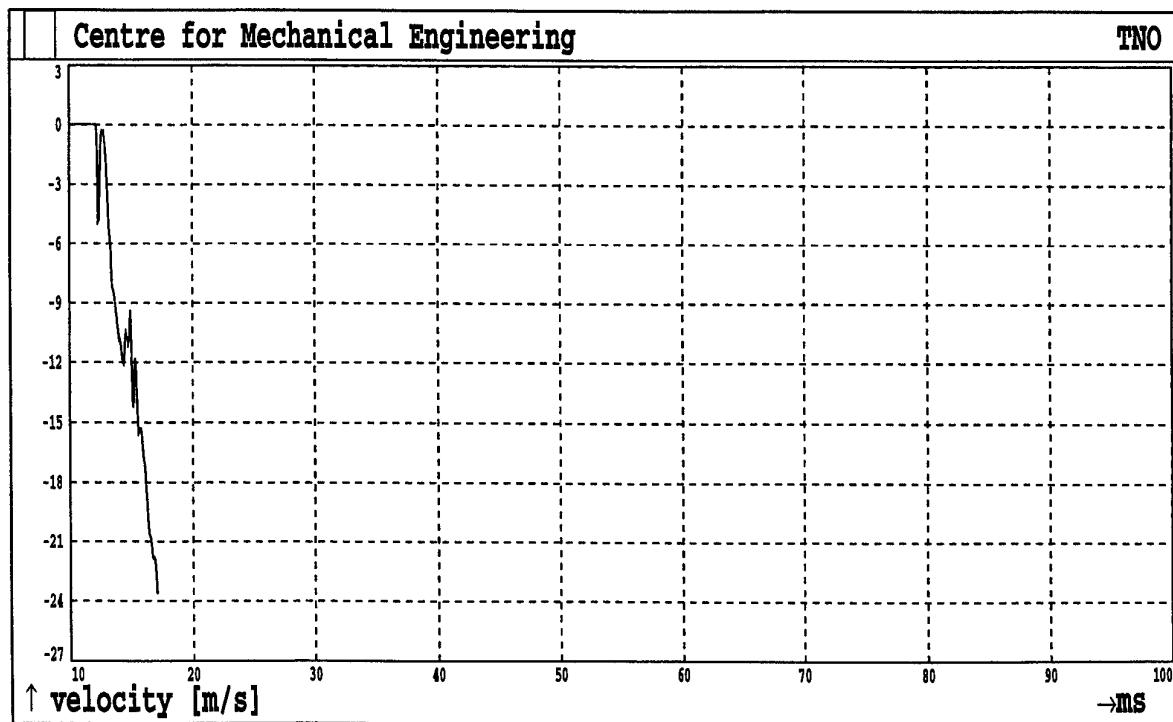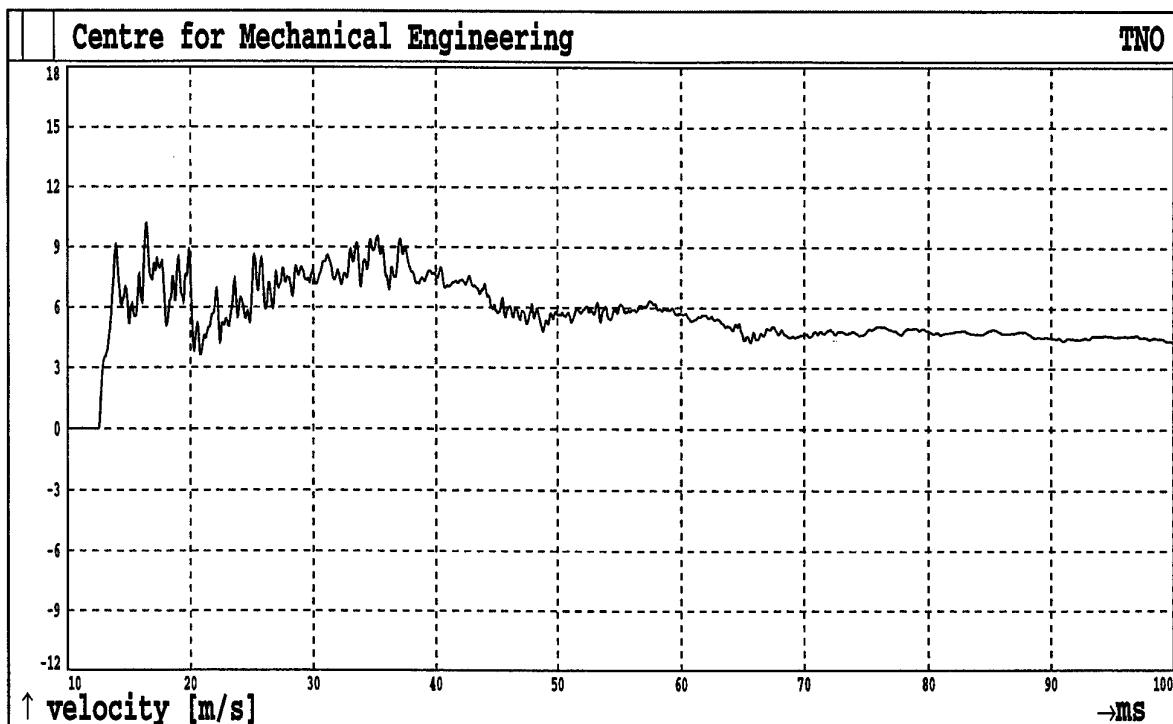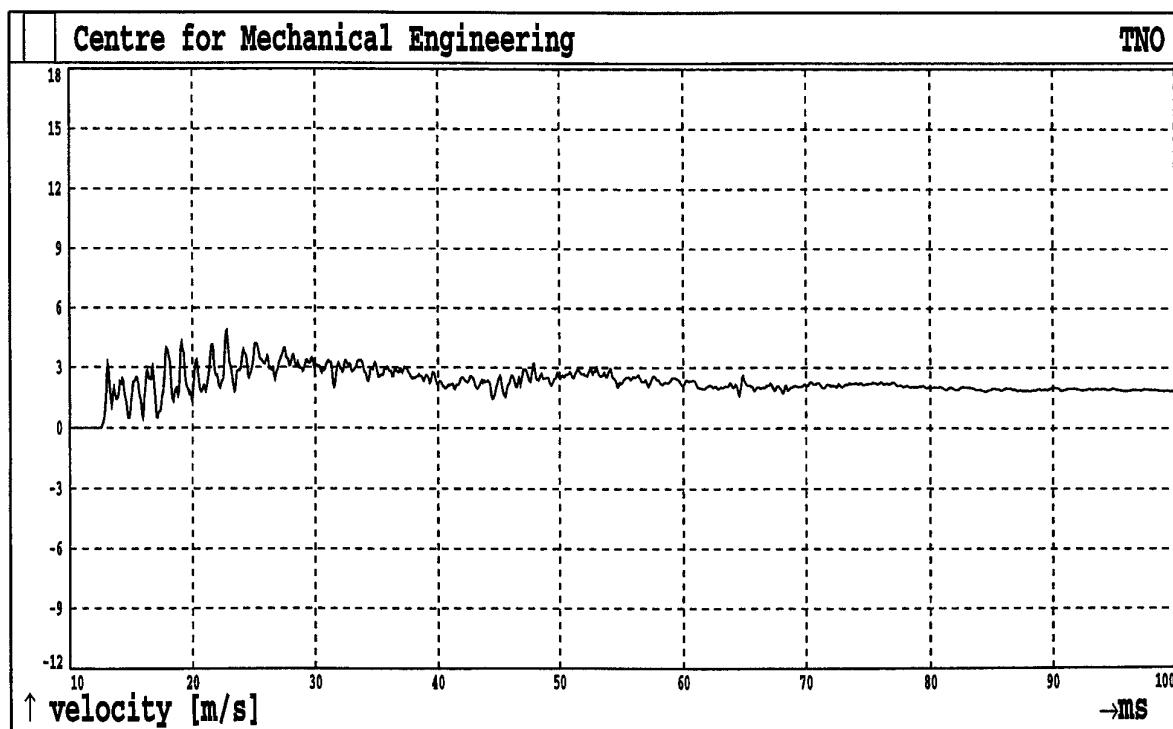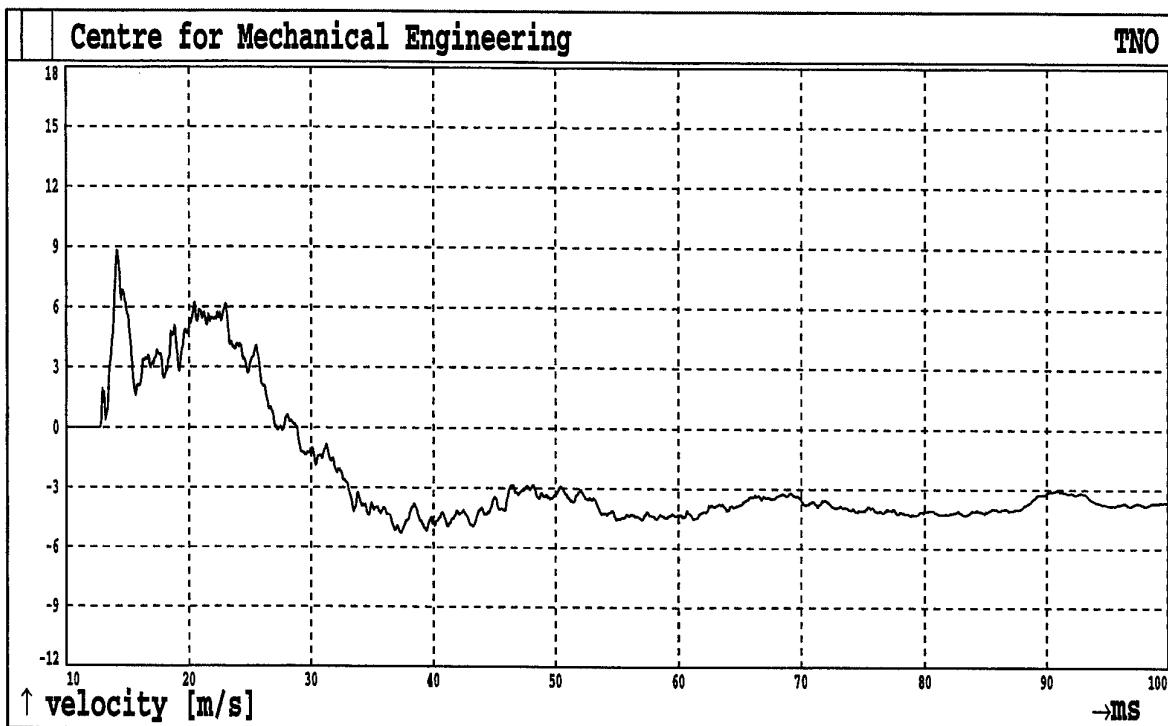
Fig.222. Shot 5   Sensor A15

Fig.223. Shot 5   Sensor A16

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Fig.224. Shot 5 Sensor A17

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Fig.225. Shot 5 Sensor A22

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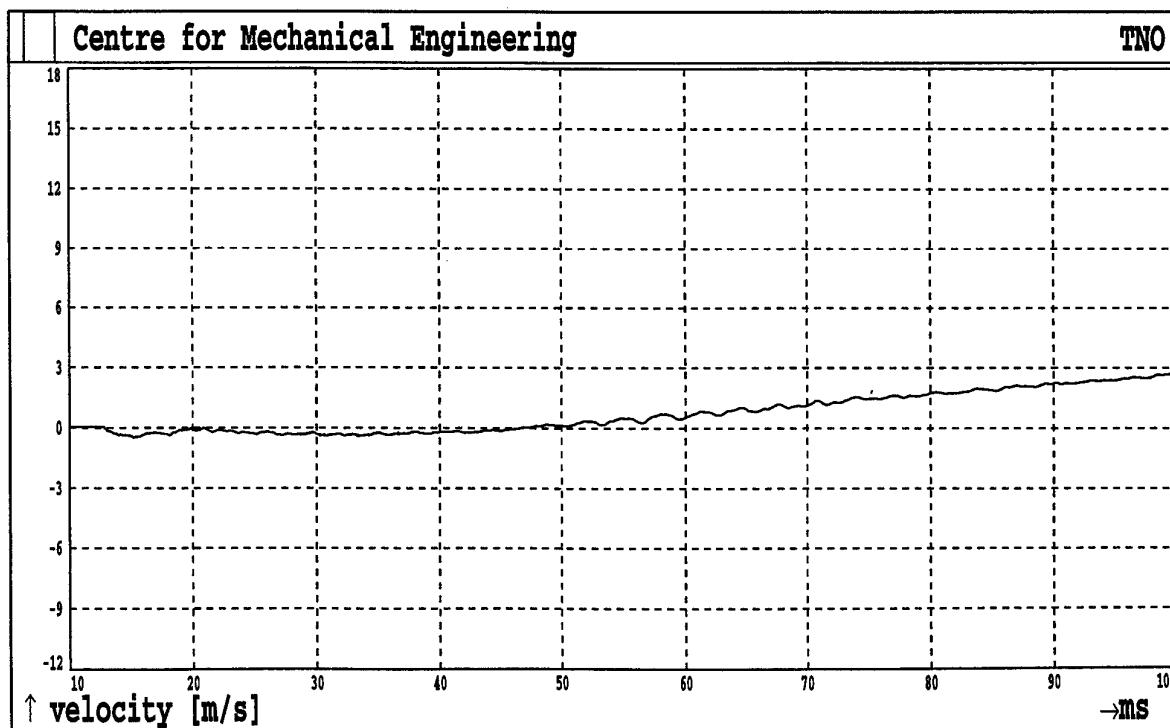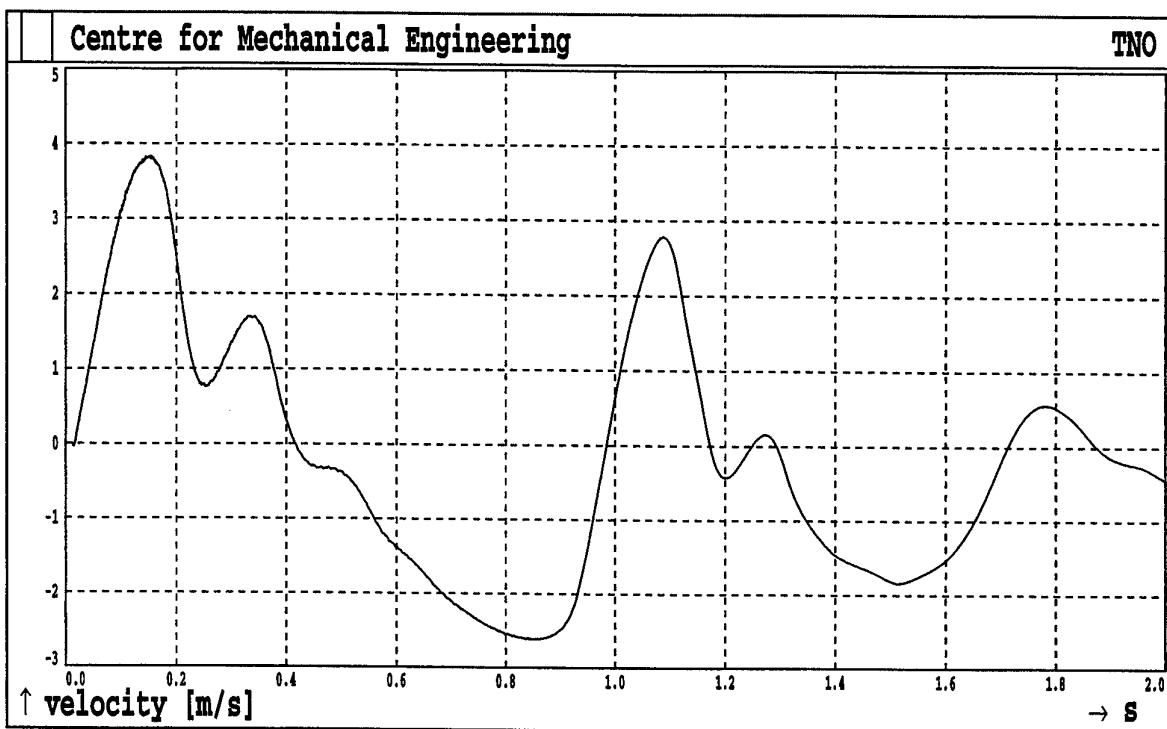
Fig.226. Shot 5   Sensor A25

Fig.227. Shot 5   Sensor A26

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Fig.228. Shot 5   Sensor A27

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Fig.229. Shot 5   Sensor A28

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Fig.230. Shot5 Sensor A2

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Fig.231. Shot5 Sensor A5

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↑ displacement [mm]   →ms

Fig.232. Shot5   Sensor A6

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↑ displacement [mm]   →ms

Fig.233. Shot5   Sensor A8

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↑ displacement [mm]   →ms

Fig.234. Shot5   Sensor A9

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↑ displacement [mm]   →ms

Fig.235. Shot5   Sensor A12

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↑ displacement [mm]   →ms

Fig.236. Shot5 Sensor A13

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↑ displacement [mm]   →ms

Fig.237. Shot5 Sensor A14

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↑ displacement [mm]   →ms

Fig.238. Shot5   Sensor A15

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↑ displacement [mm]   →ms

Fig.239. Shot5   Sensor A16

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Fig.240. Shot5   Sensor A17

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Fig.241. Shot5   Sensor A22

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Fig.242. Shot5   Sensor A25

Fig.243. Shot5   Sensor A26

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↑ displacement [mm] → s

Fig.244. Shot5 Sensor A27

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↑ displacement [mm] → s

Fig.245. Shot5 Sensor A28

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↑ displacement [mm]   → s
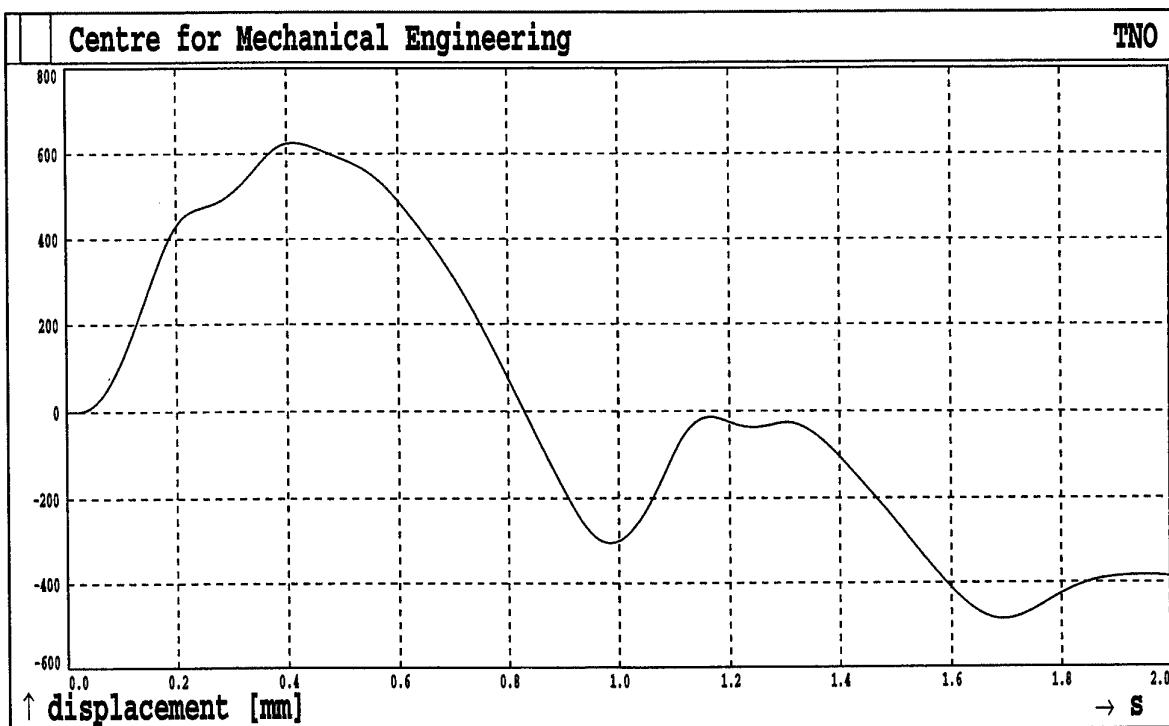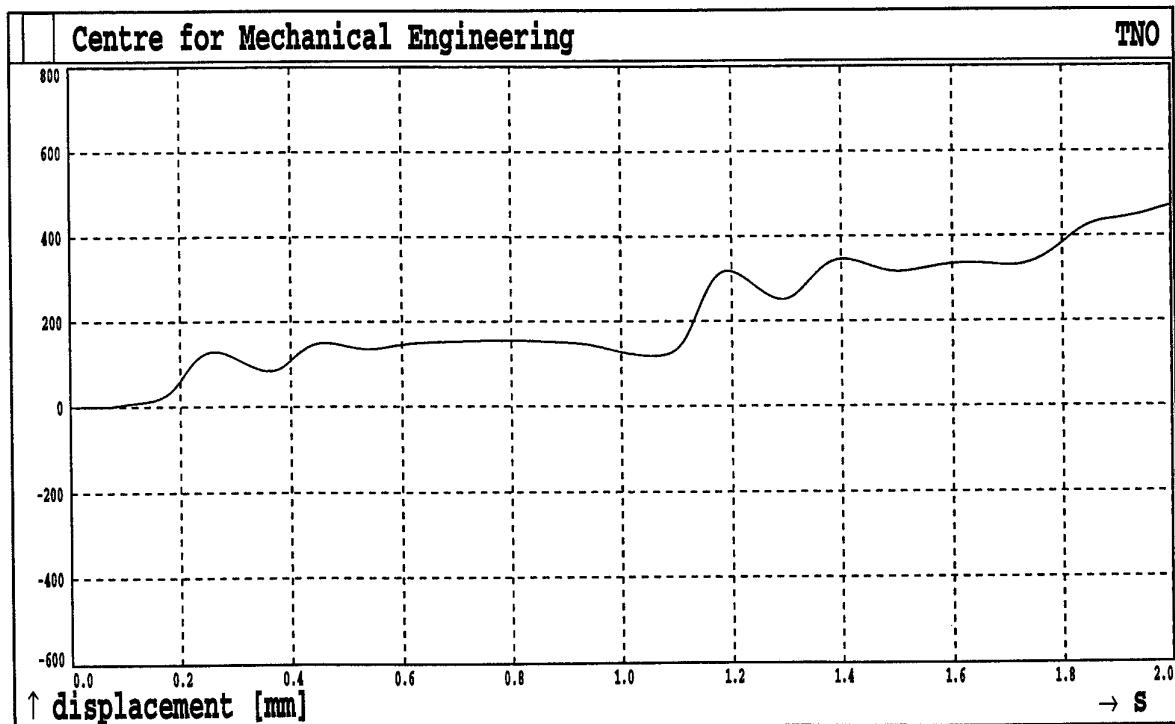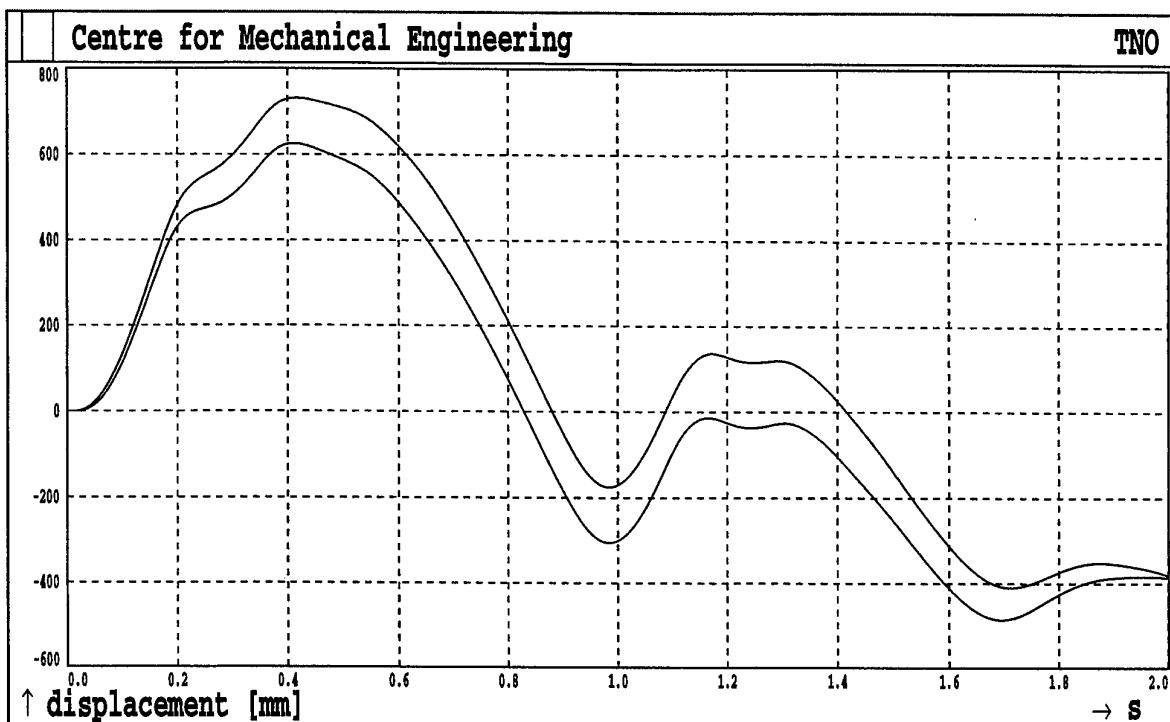
Fig.246. Shot5 Sensor A25 and sensor A27

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↑ displacement [mm]   → s
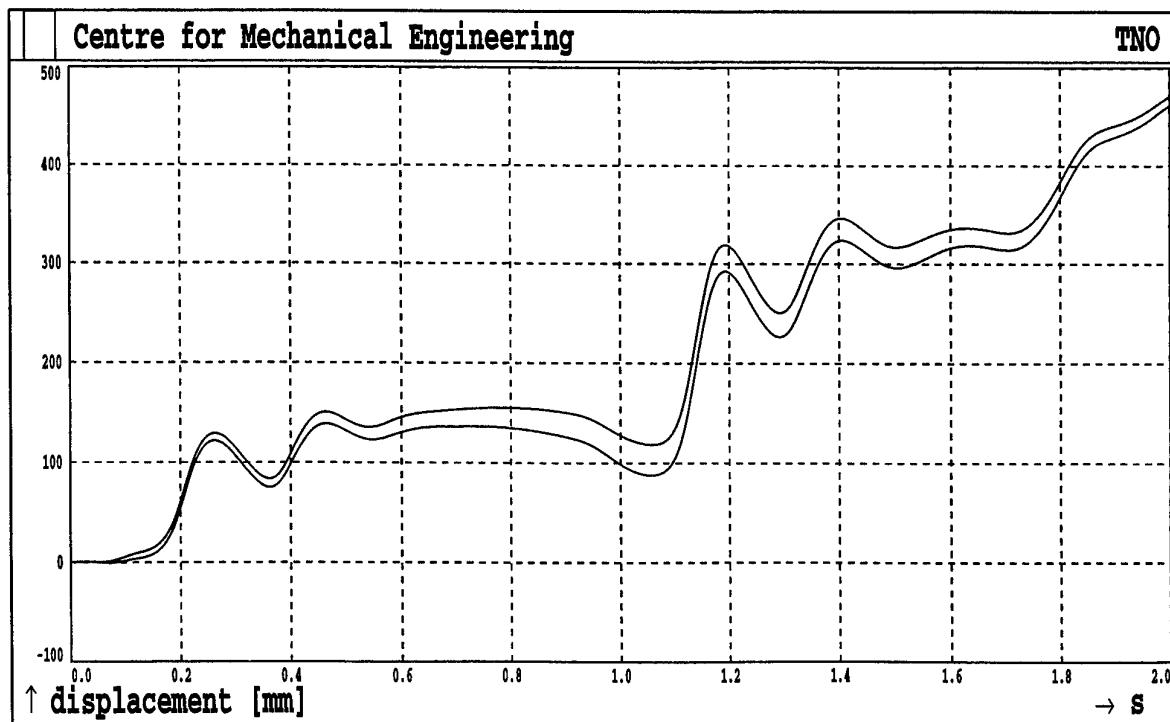
Fig.247. Shot5 Sensor A26 and sensor A28

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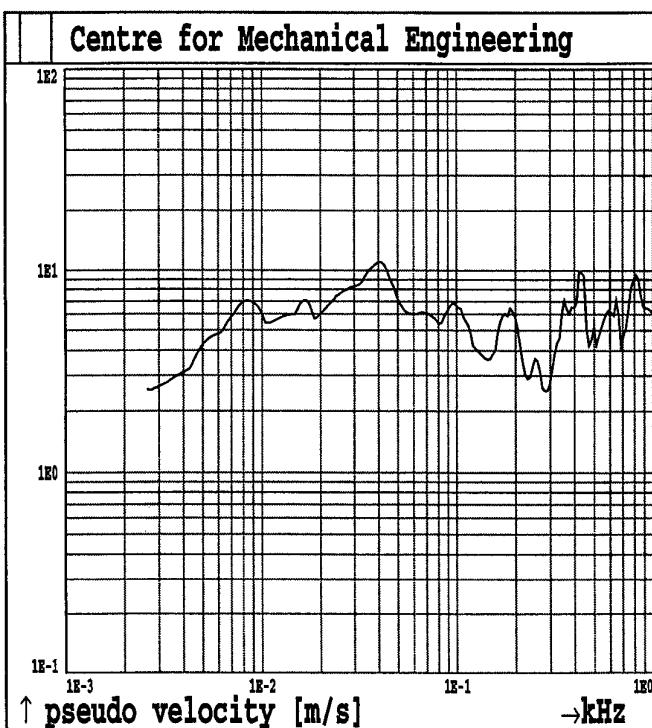
Fig.248. Shot 5 MAXIMAX Sensor A2
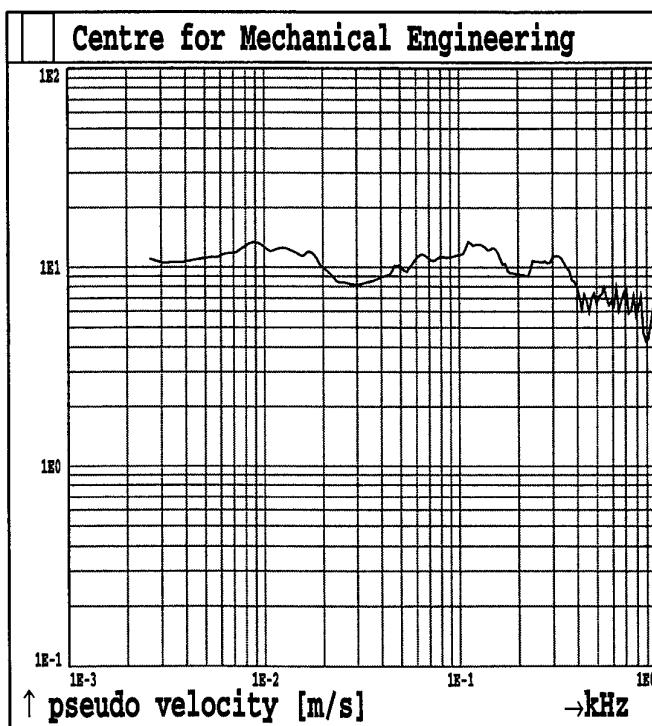
Fig.249. Shot 5 MAXIMAX Sensor A5

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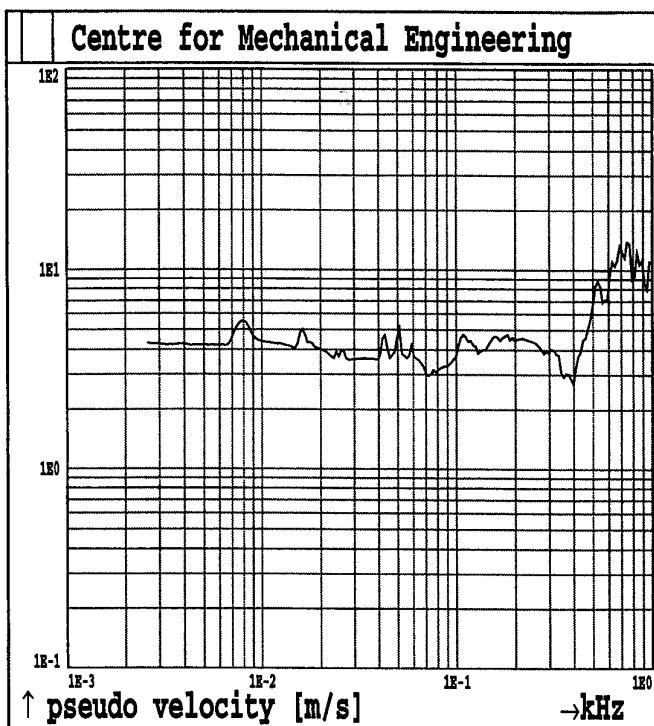
Fig.250. Shot 5 MAXIMAX Sensor A6

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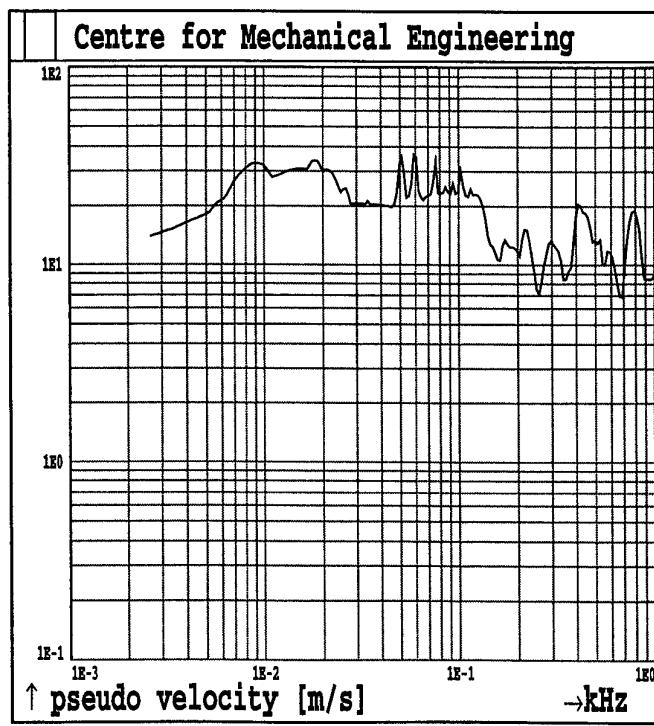
Fig.251. Shot 5 MAXIMAX Sensor A8

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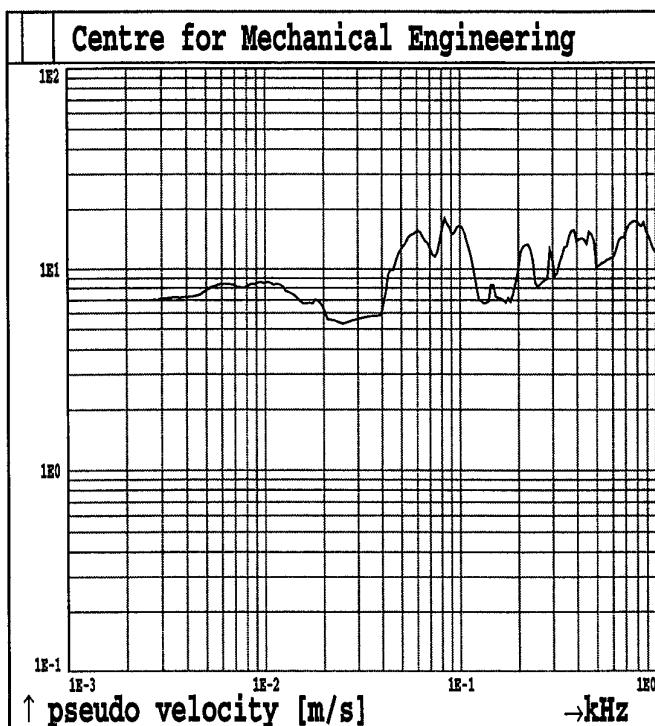
Fig.252. Shot 5 MAXIMAX Sensor A9
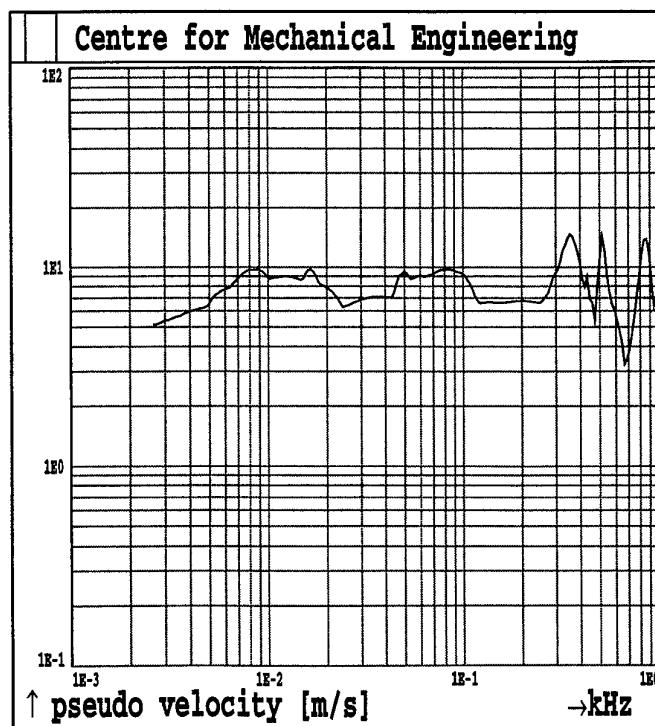
Fig.253. Shot 5 MAXIMAX Sensor A13

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↑ pseudo velocity [m/s]   →kHz
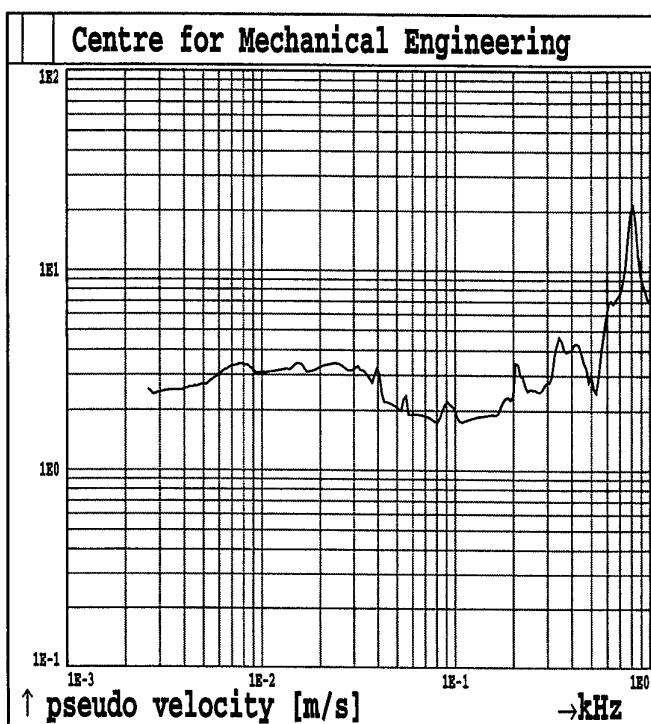
Fig.254. Shot 5 MAXIMAX Sensor A14

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↑ pseudo velocity [m/s]   →kHz
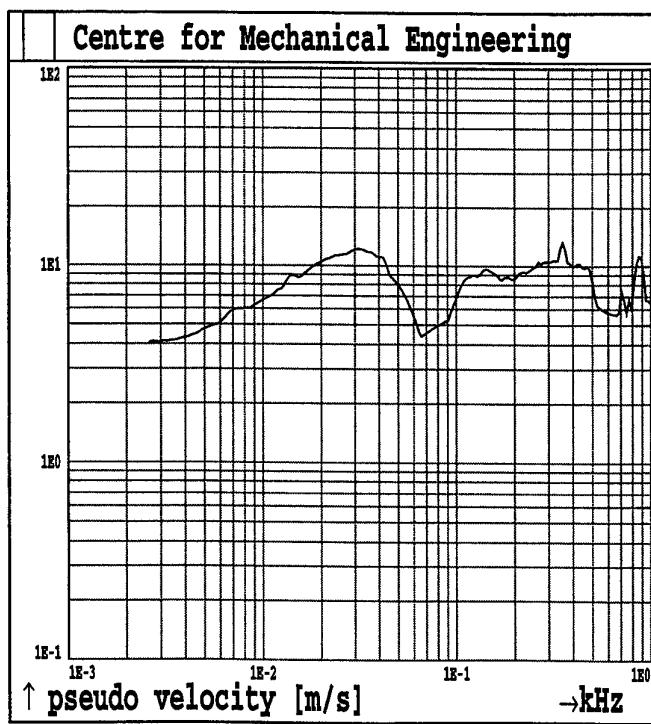
Fig.255. Shot 5 MAXIMAX Sensor A15

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↑ pseudo velocity [m/s]   →kHz
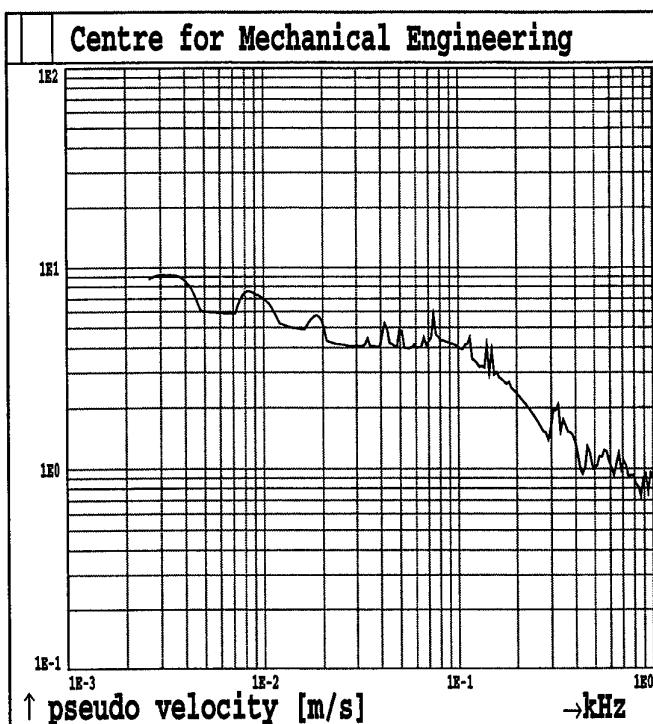
Fig.256. Shot 5 MAXIMAX Sensor A17

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↑ pseudo velocity [m/s]   →kHz
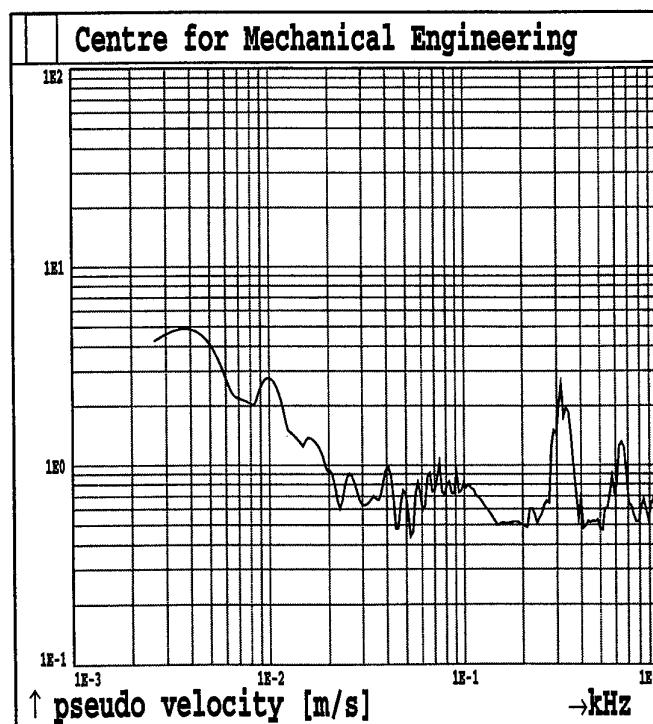
Fig.257. Shot 5 MAXIMAX Sensor A22

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↑ pseudo velocity [m/s]   →kHz

Fig.258. Shot 5 MAXIMAX Sensor A25

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↑ pseudo velocity [m/s]   →kHz

Fig.259. Shot 5 MAXIMAX Sensor A26

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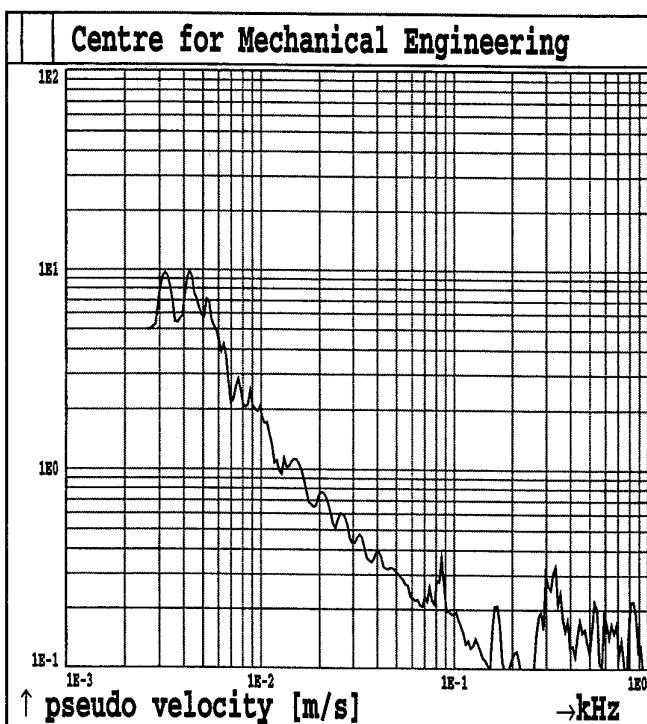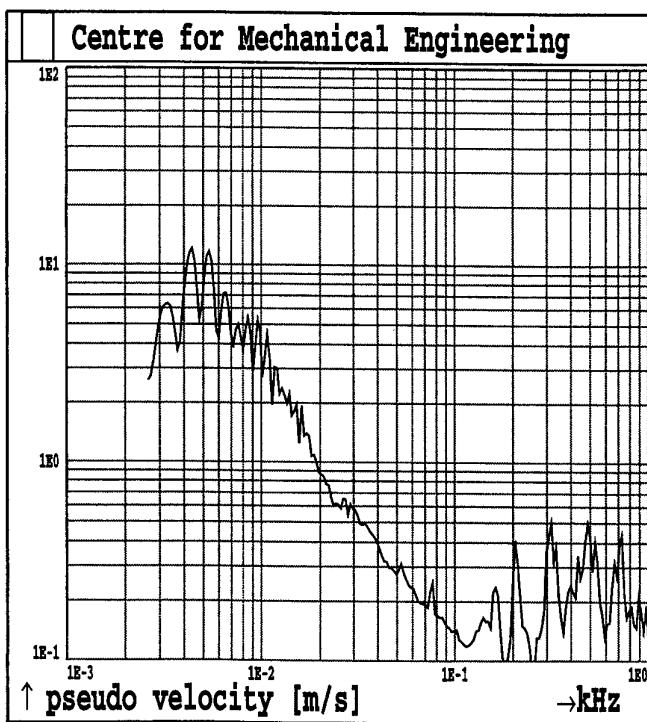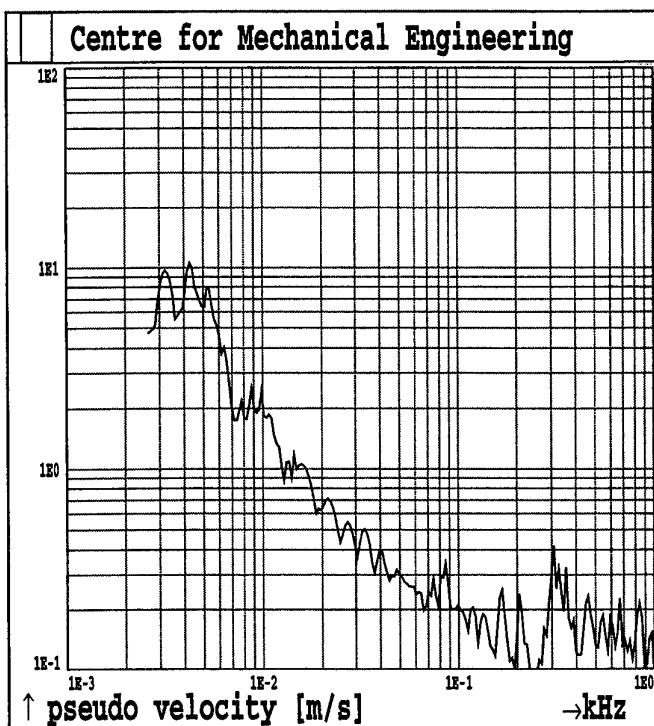
Fig.260. Shot 5 MAXIMAX Sensor A27
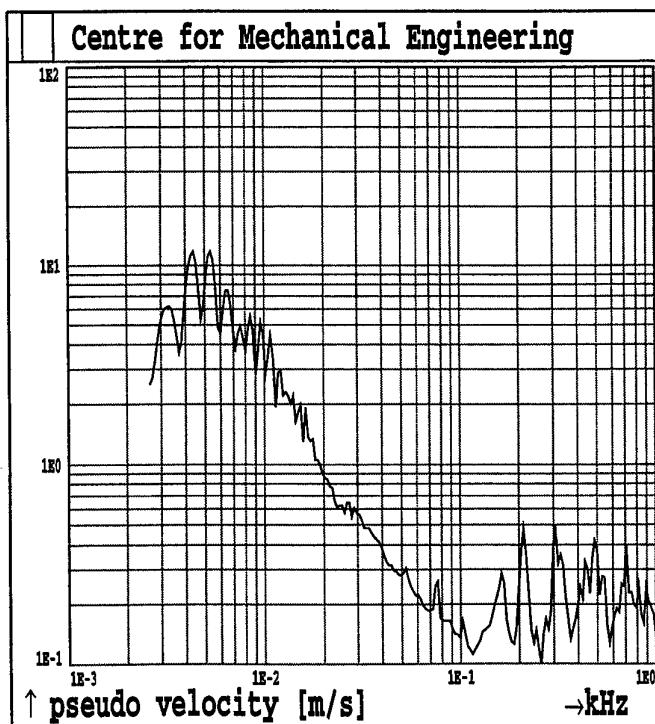
Fig.261. Shot 5 MAXIMAX Sensor A28

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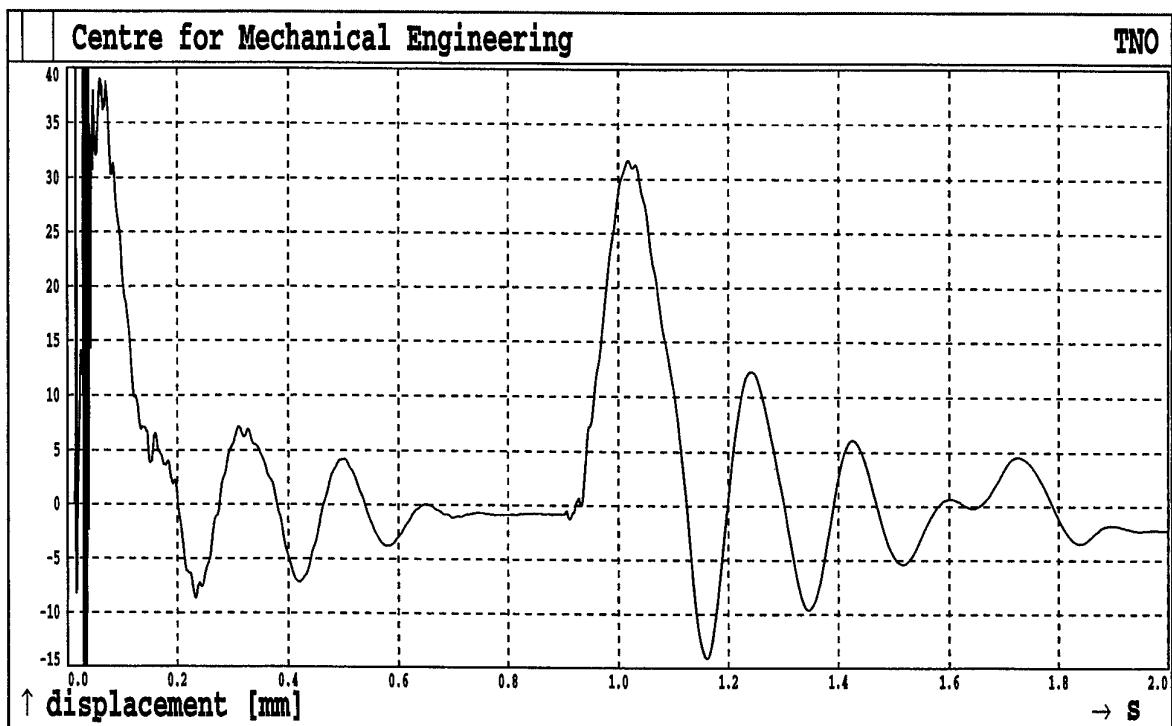
Fig.262. Shot 5   Sensor R2

Fig.263. Shot 5   Sensor R4

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Fig.264. Shot 5   Sensor R2

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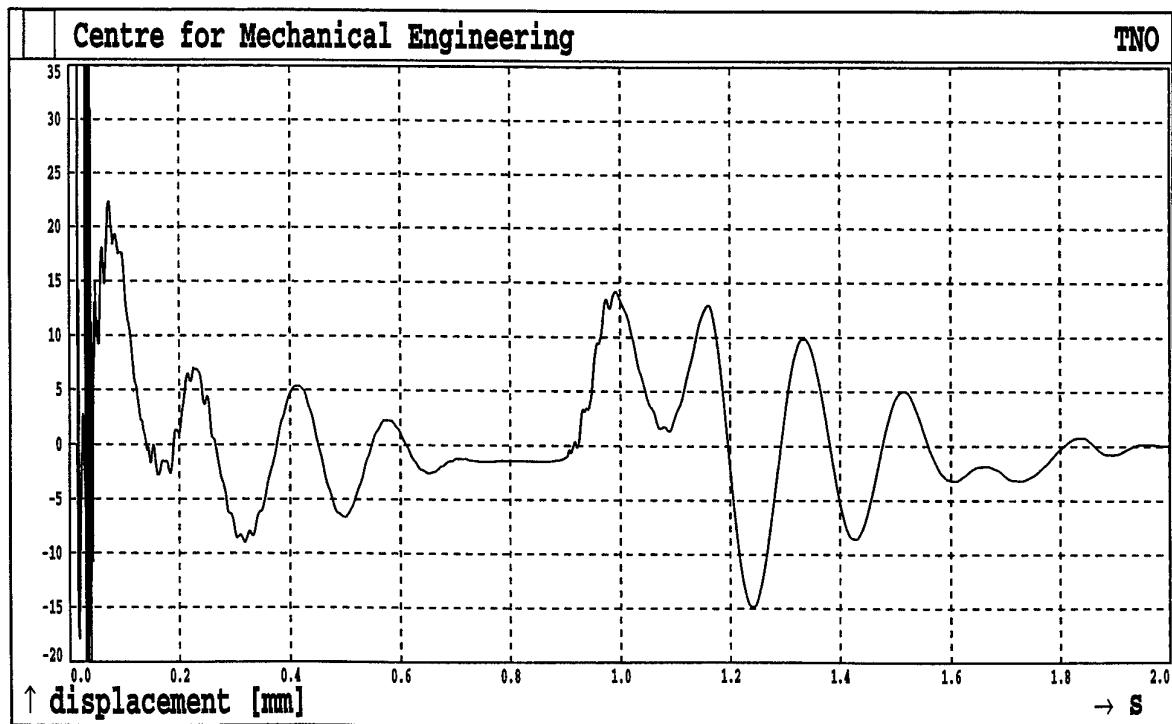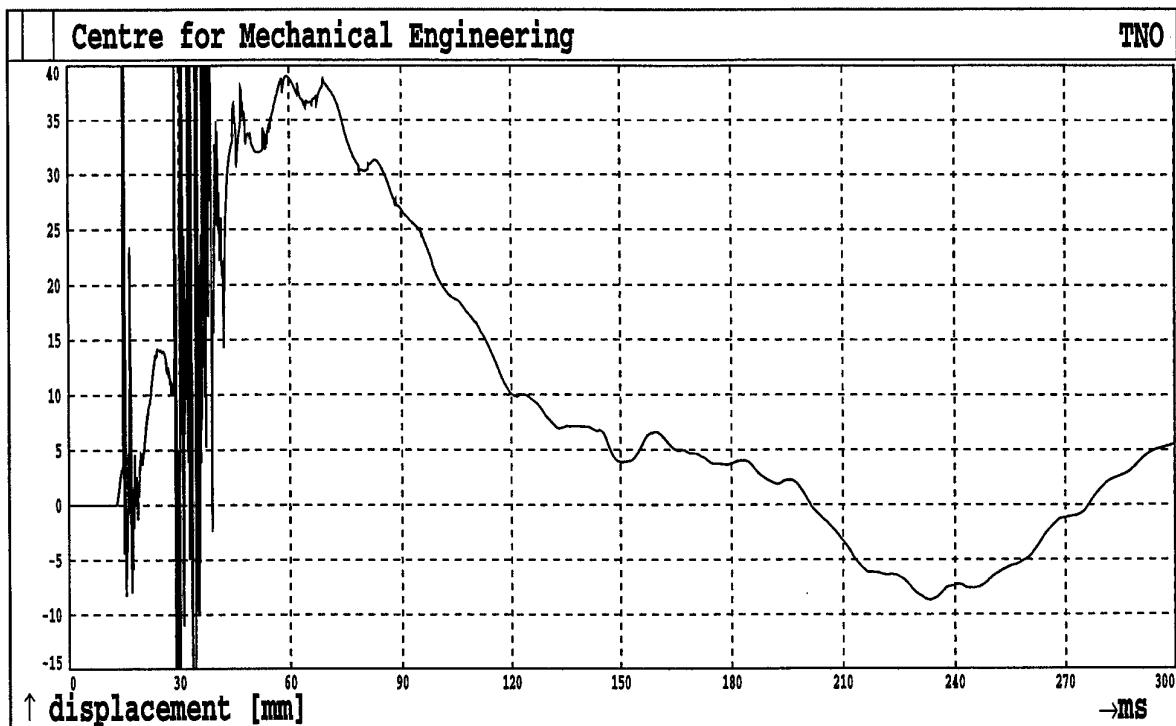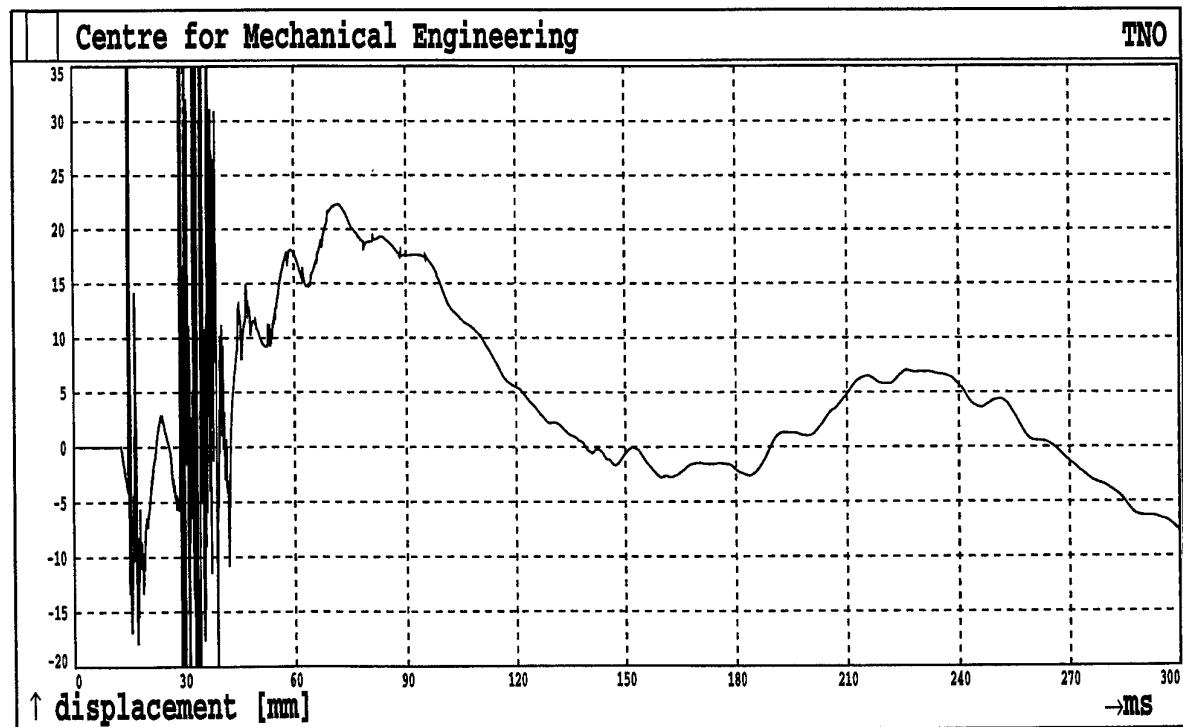
Fig.265. Shot 5   Sensor R4

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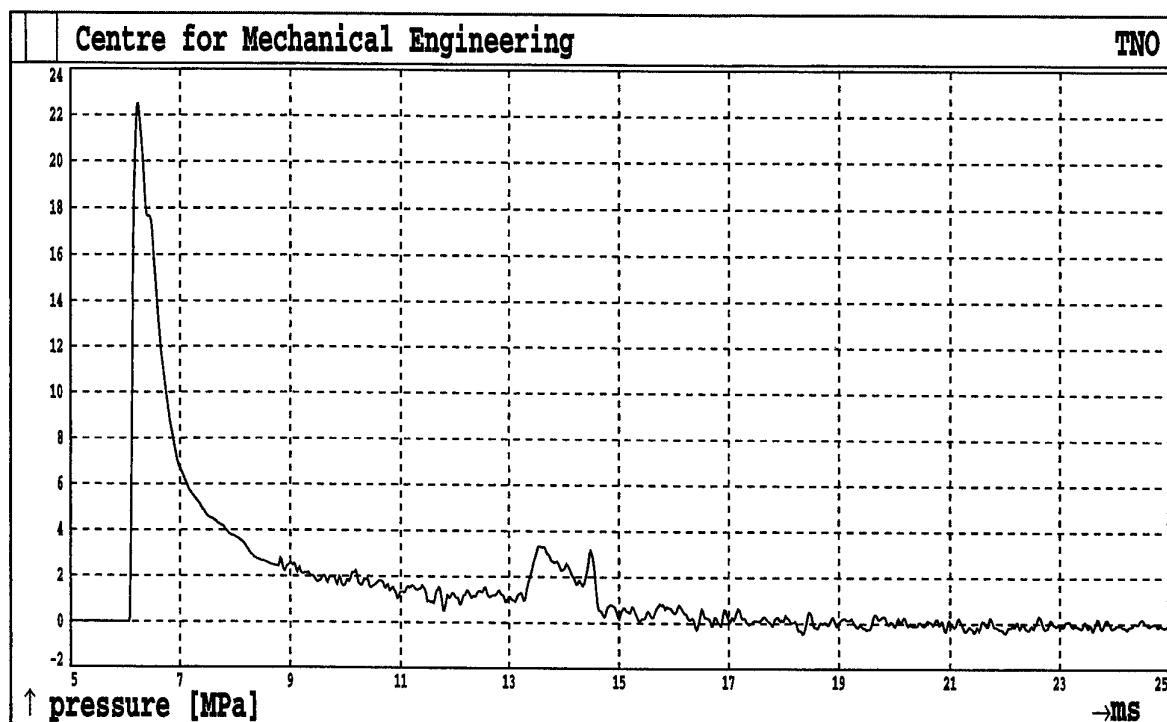
Fig.266. Shot 6   Sensor P1
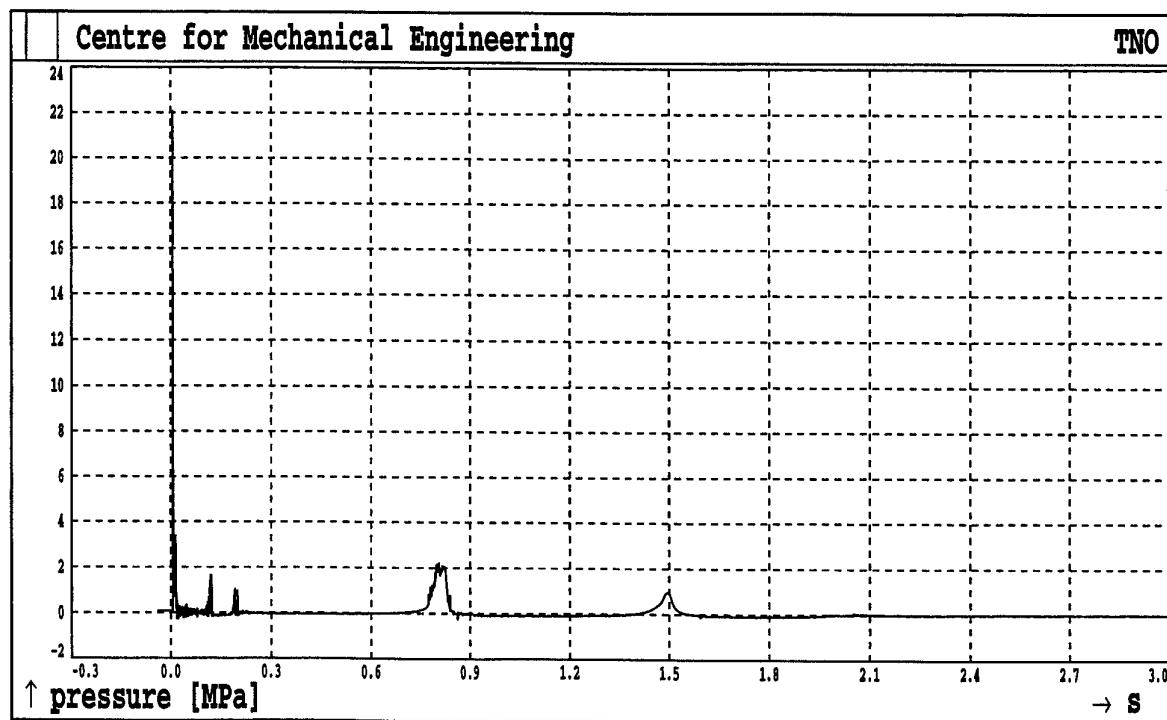
Fig.267. Shot 6   Sensor P1

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Fig.268. Shot 6 Sensor P1

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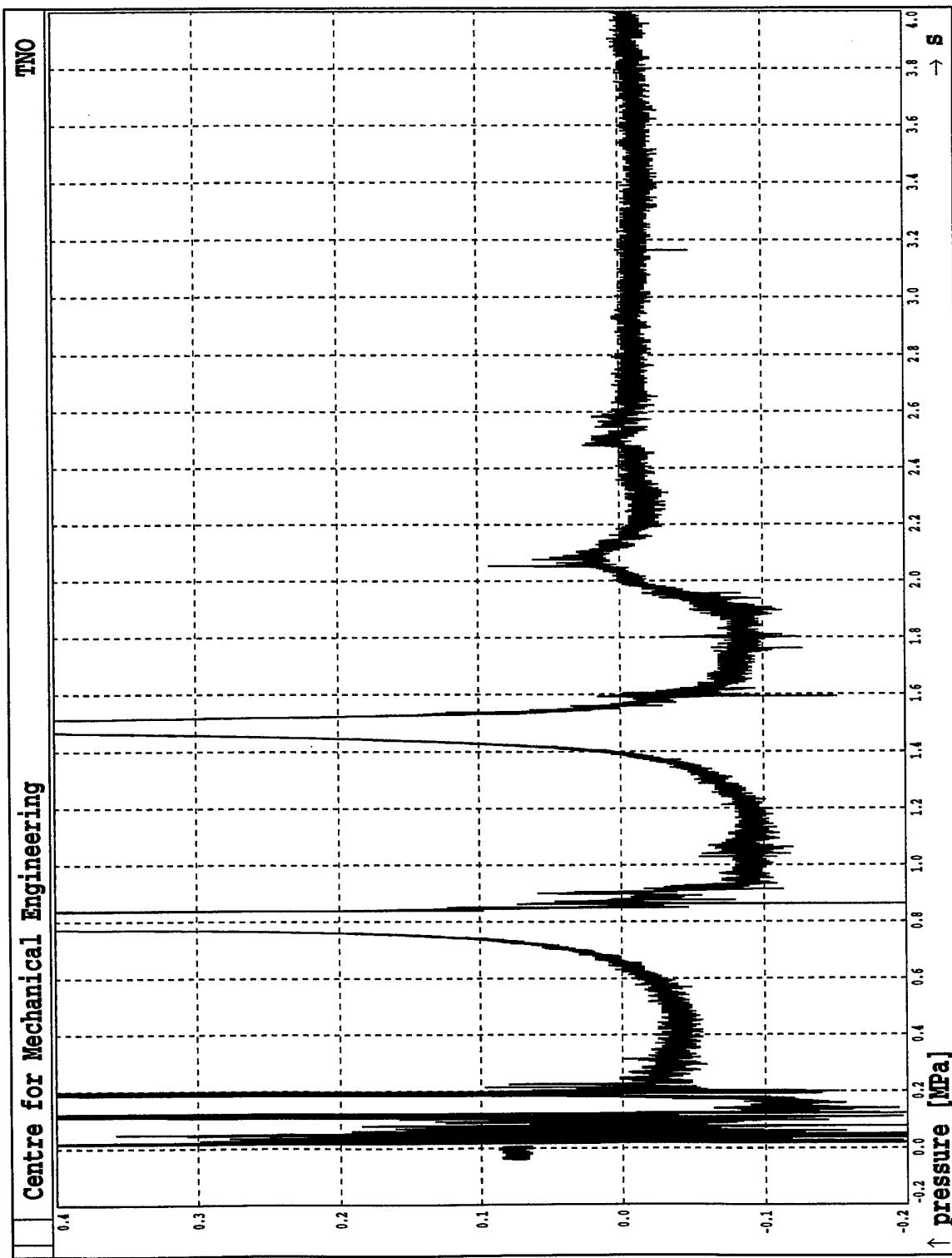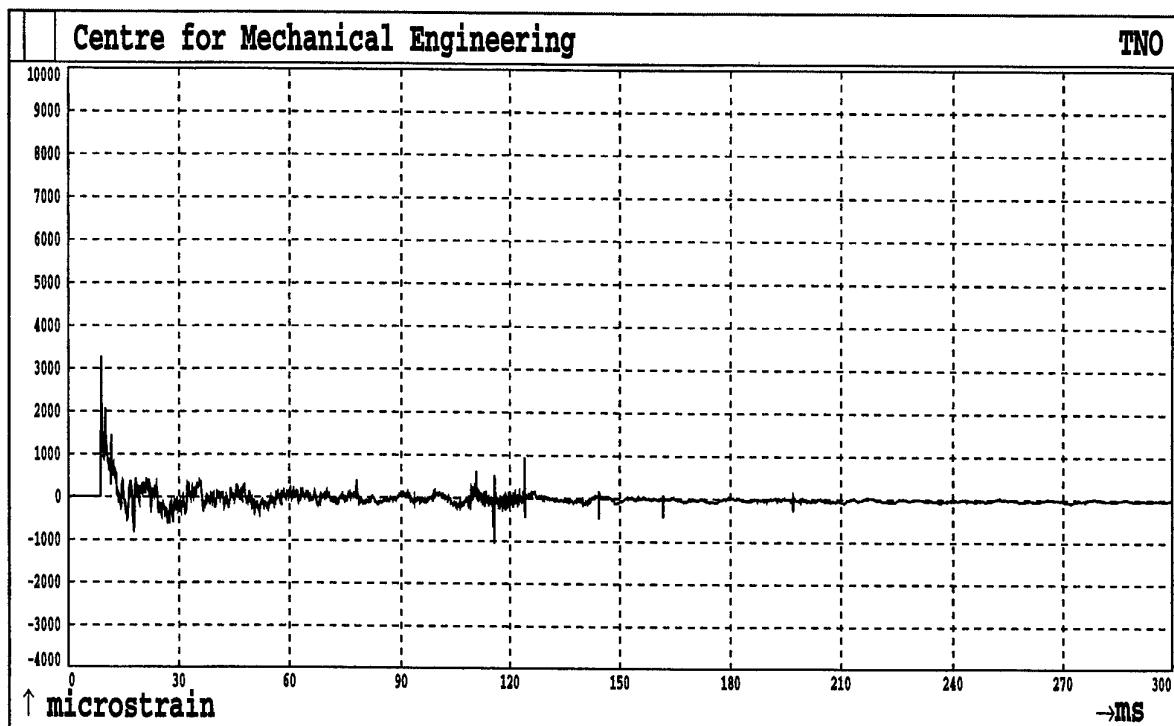
Fig.269. Shot 6   Sensor S1

Fig.270. Shot 6   Sensor S2

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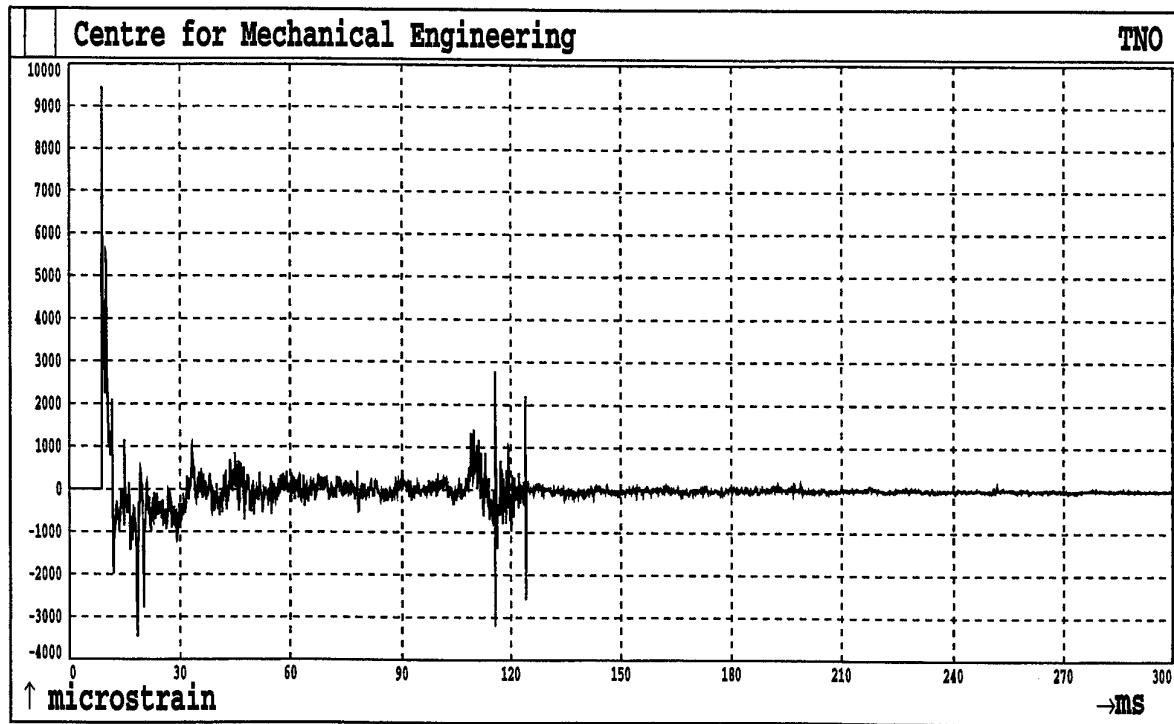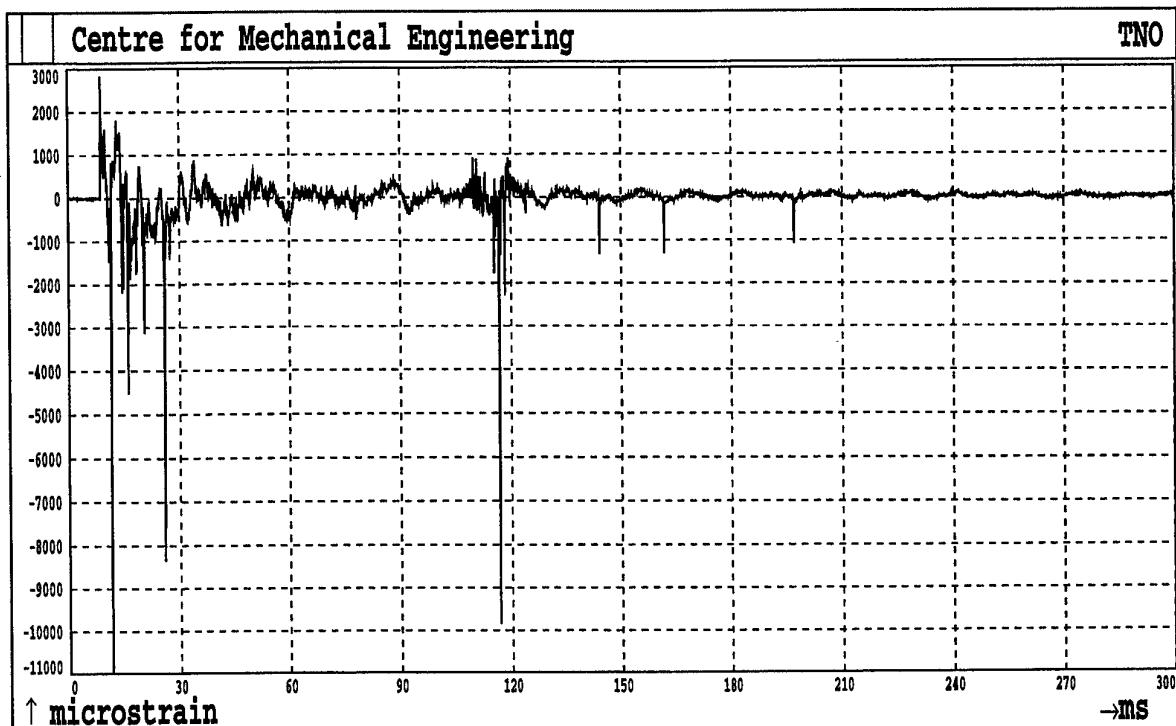
Fig.271. Shot 6   Sensor S3

Fig.272. Shot 6   Sensor S4
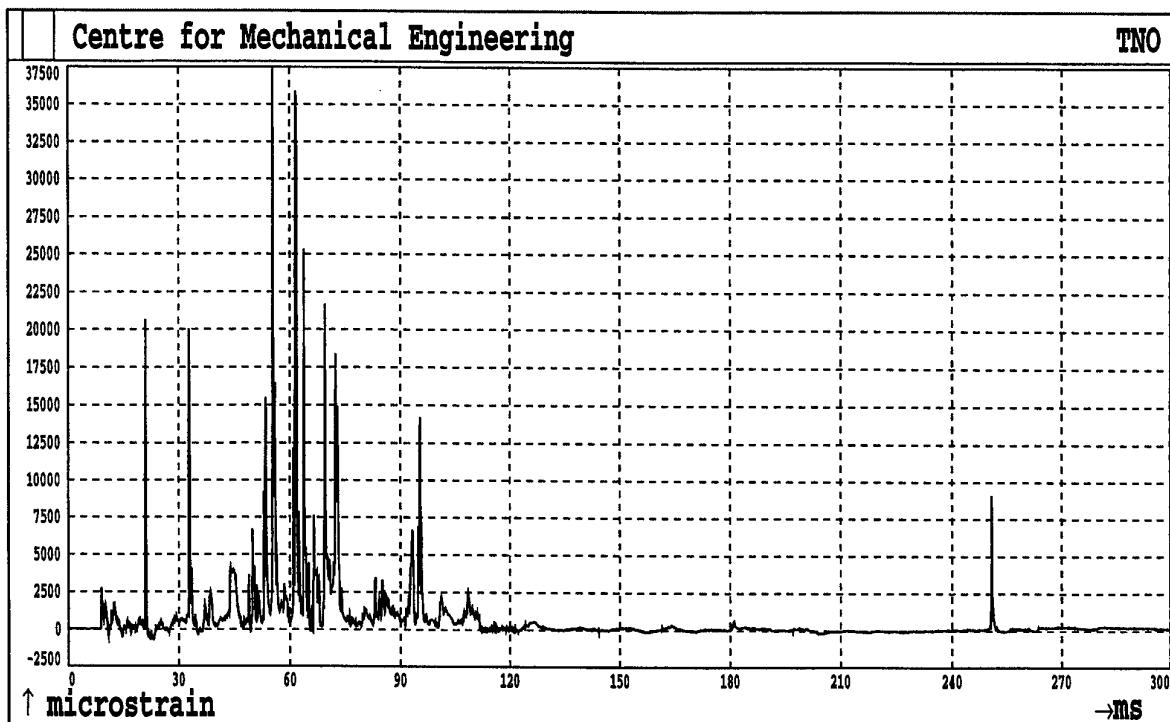
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Fig.273. Shot 6   Sensor S5

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Fig.274. Shot 6   Sensor S6

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↑ microstrain   →ms

Fig.275. Shot 6   Sensor S7

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↑ microstrain   →ms

Fig.276. Shot 6   Sensor S8

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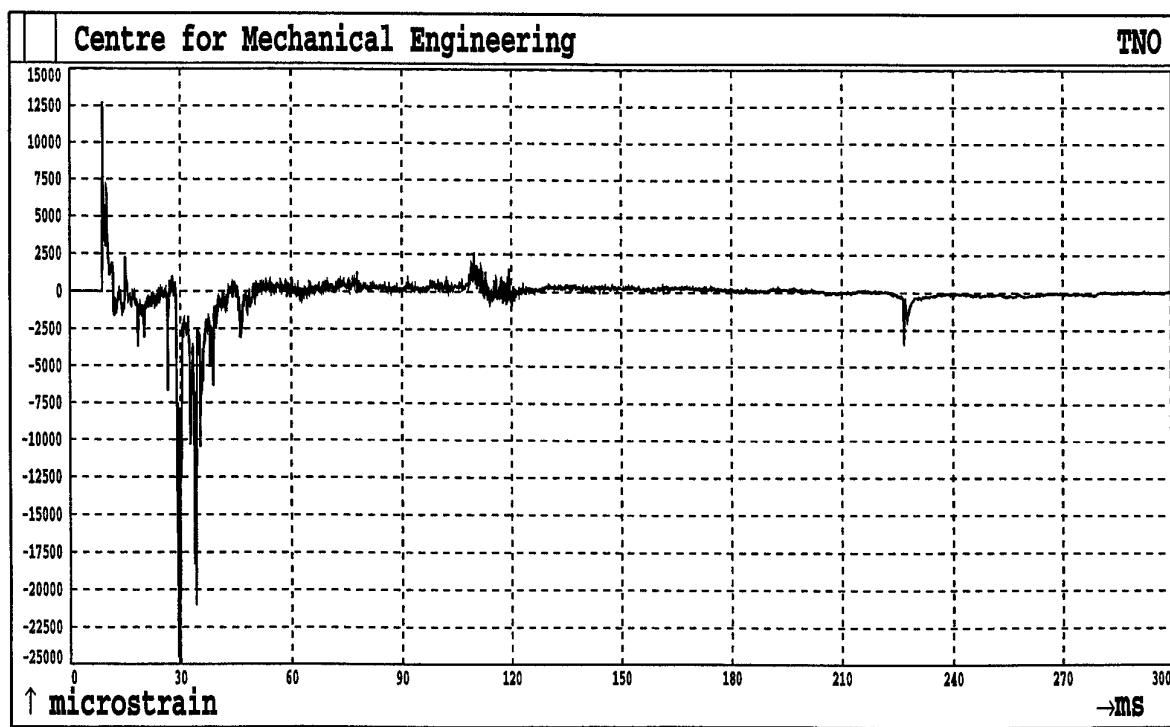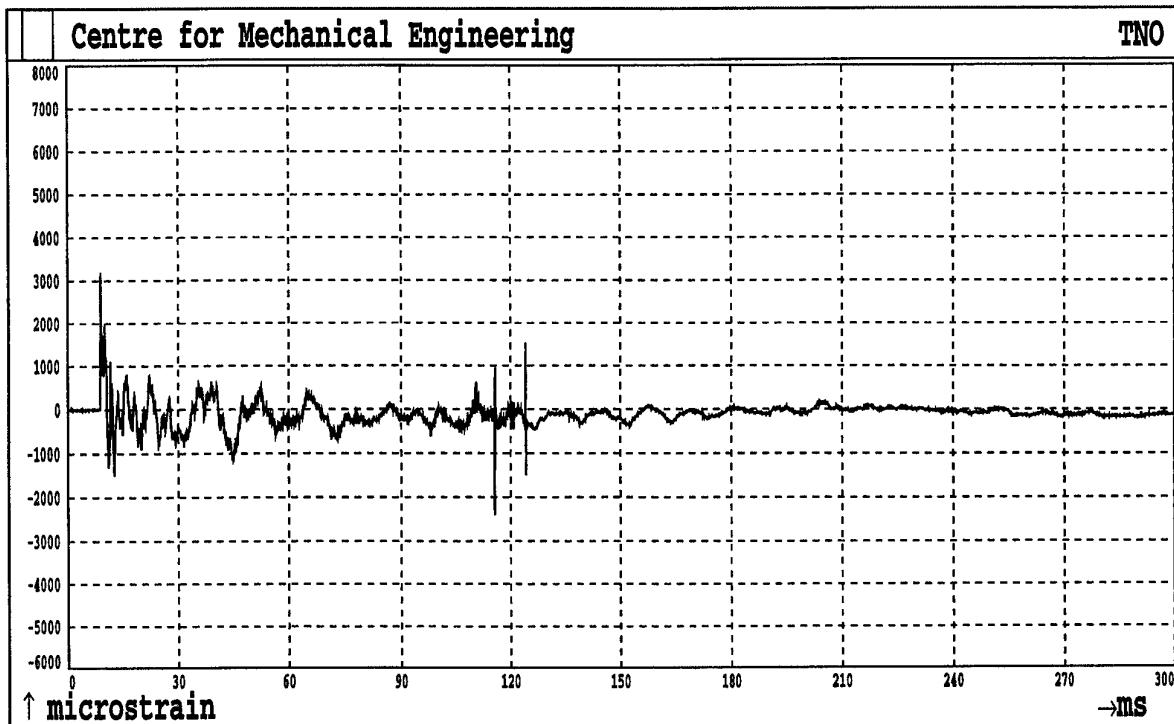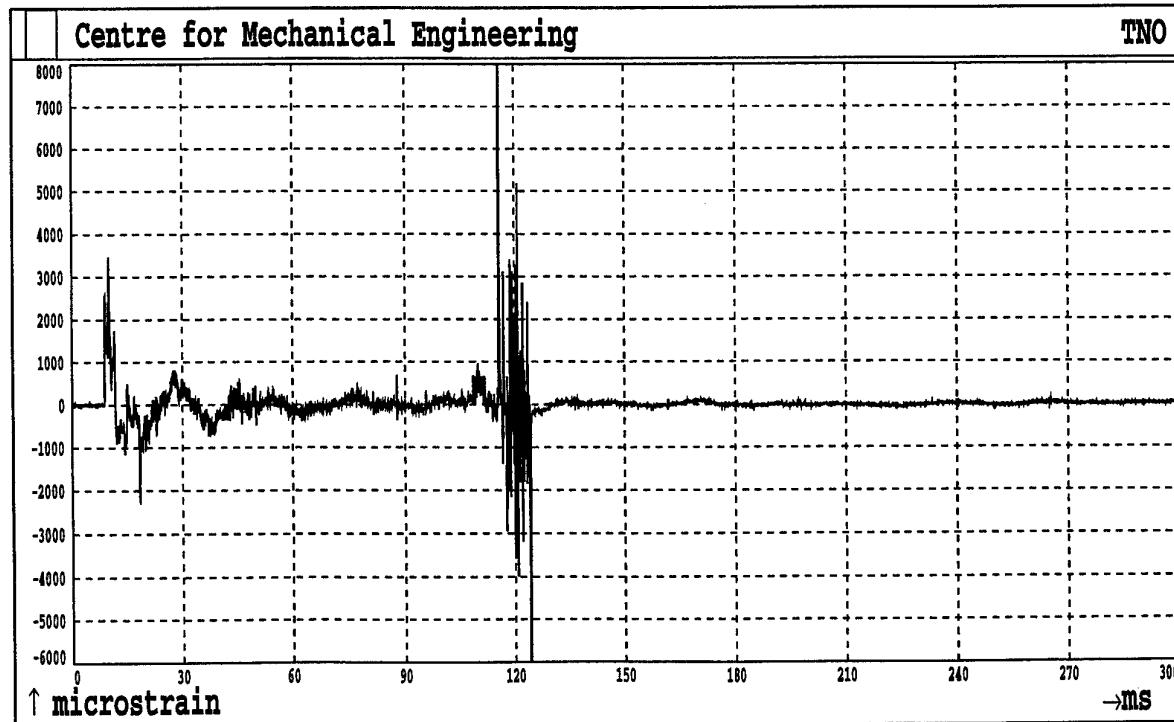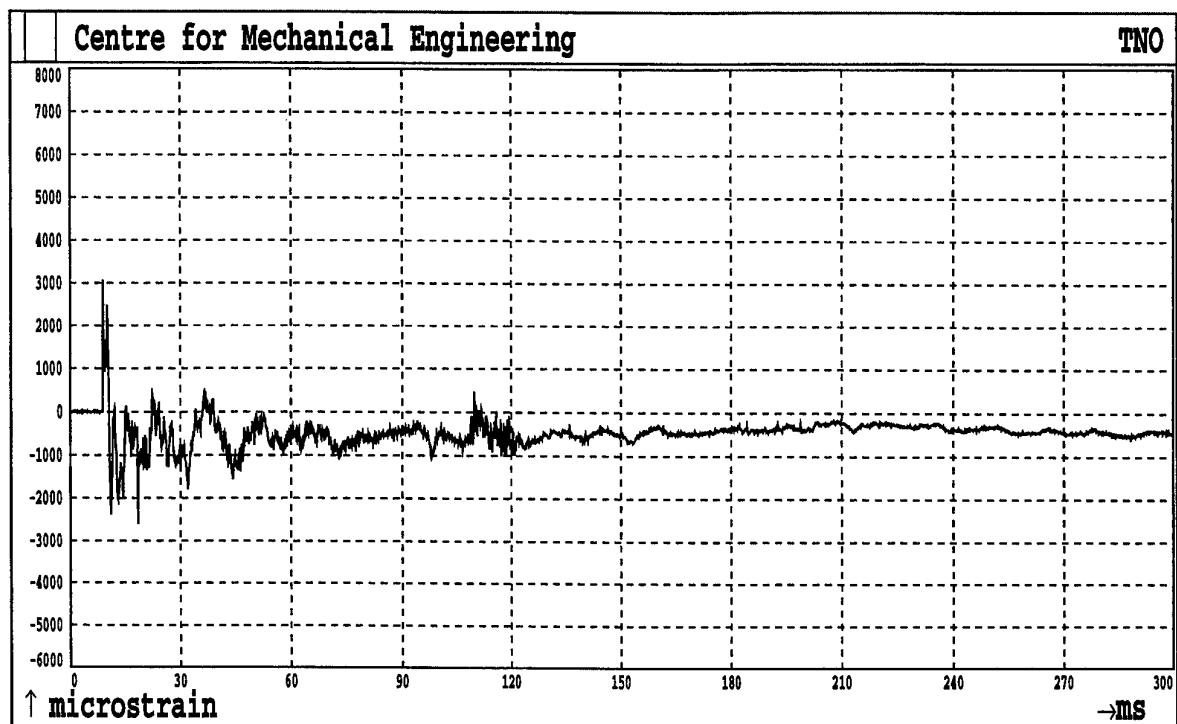
Fig.277. Shot 6   Sensor S11

Fig.278. Shot 6   Sensor S12

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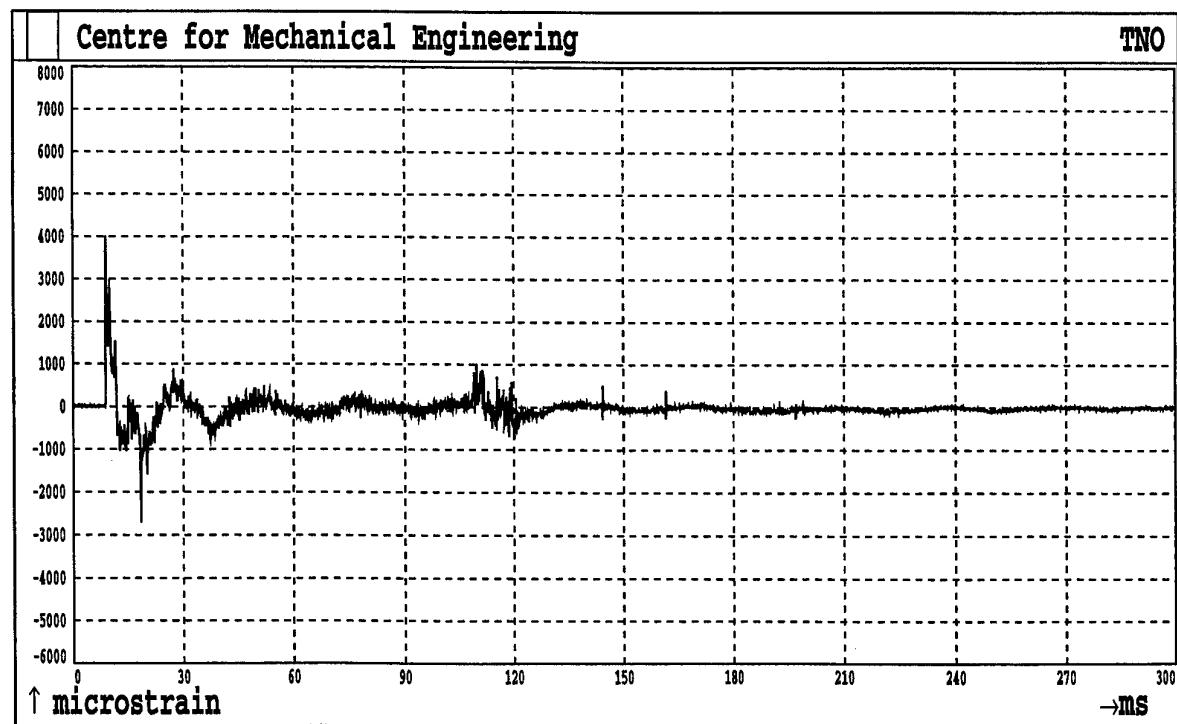
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A.142
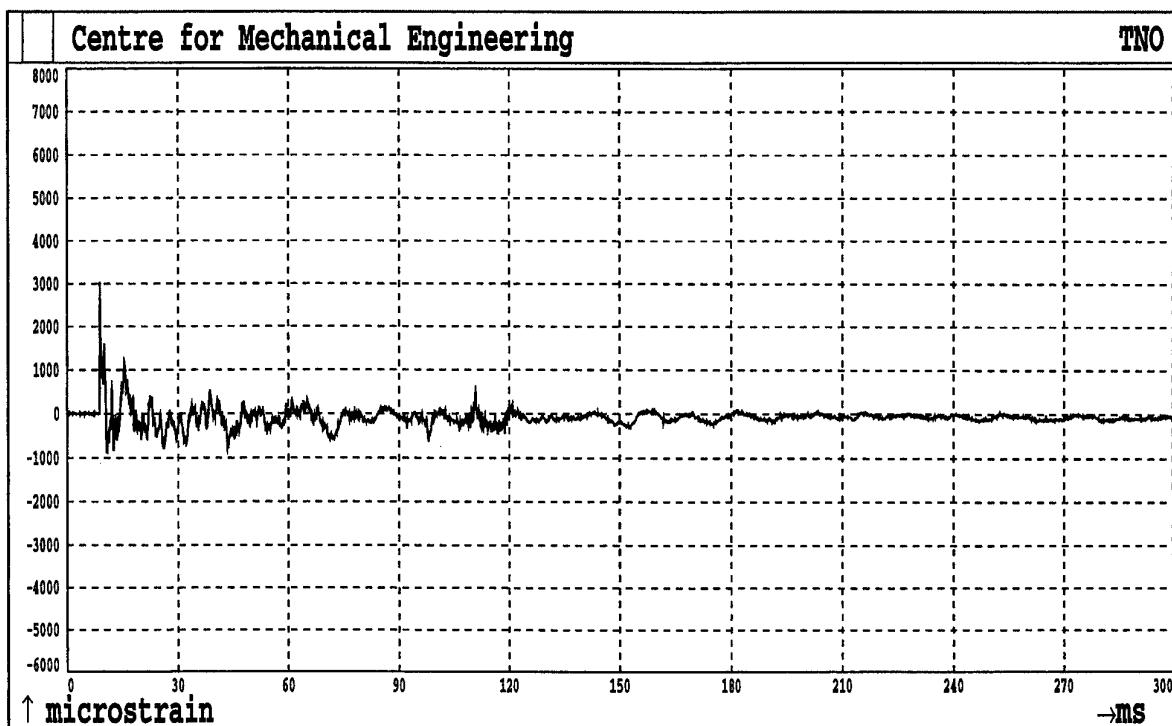
Fig.279. Shot 6 Sensor S13

Fig.280. Shot 6 Sensor S14

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A.143
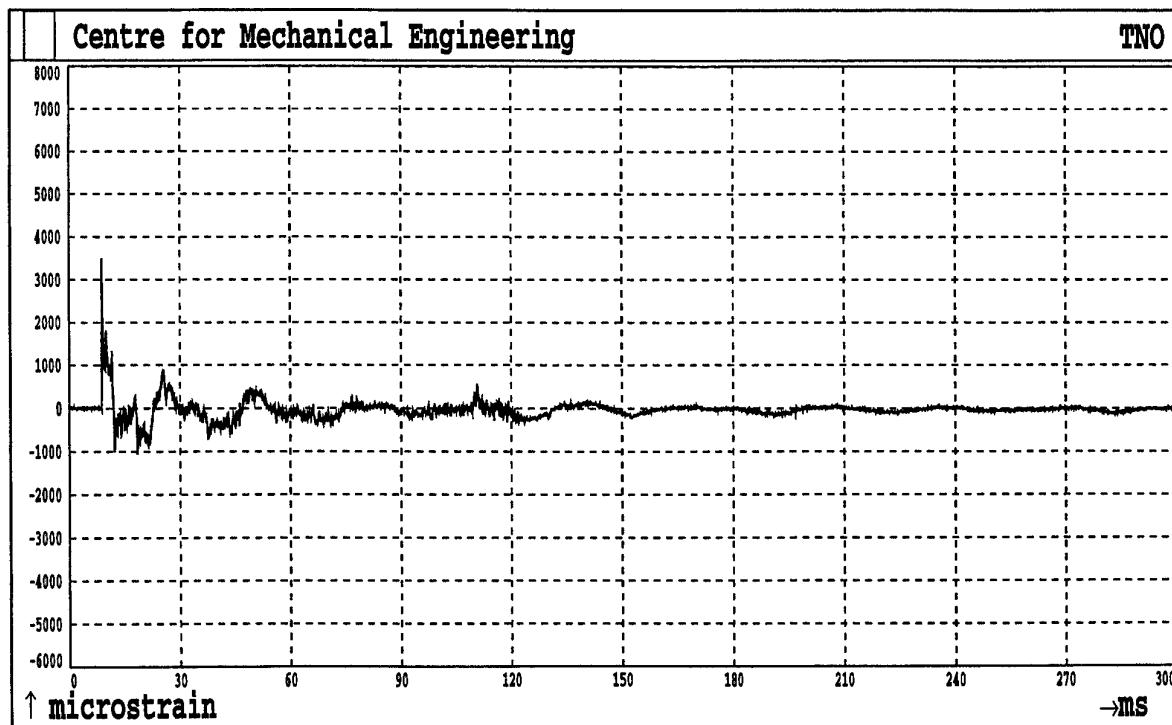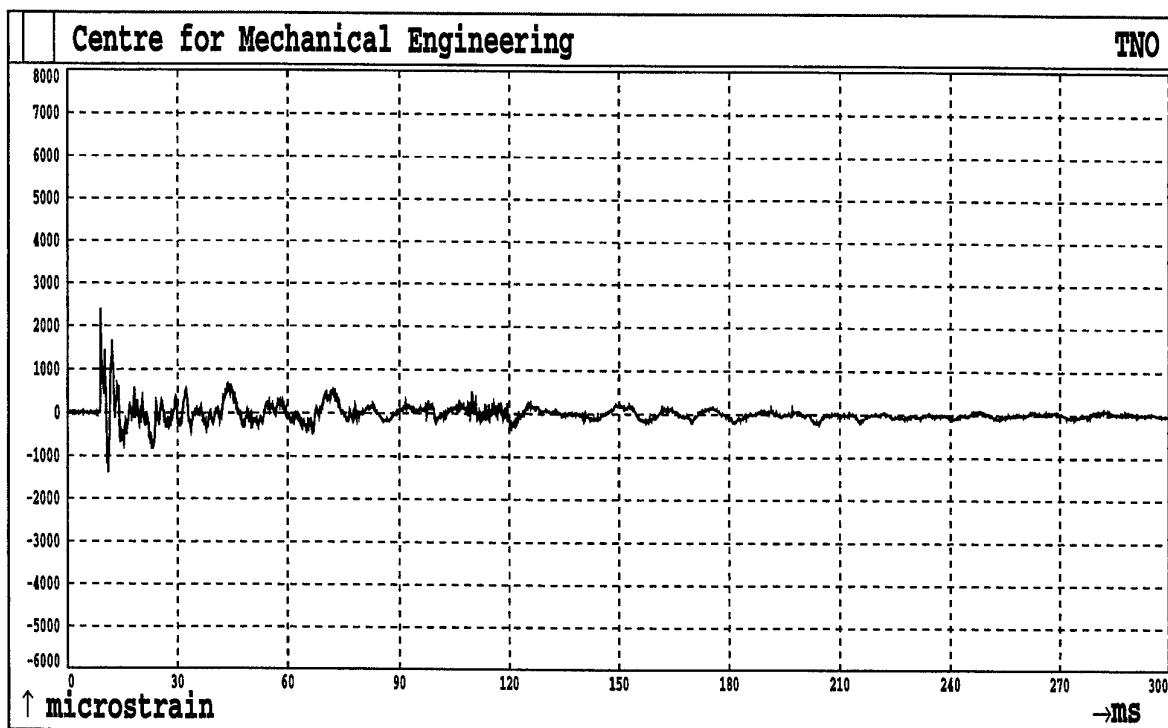
Fig.281. Shot 6   Sensor S15

Fig.282. Shot 6   Sensor S16

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A.144
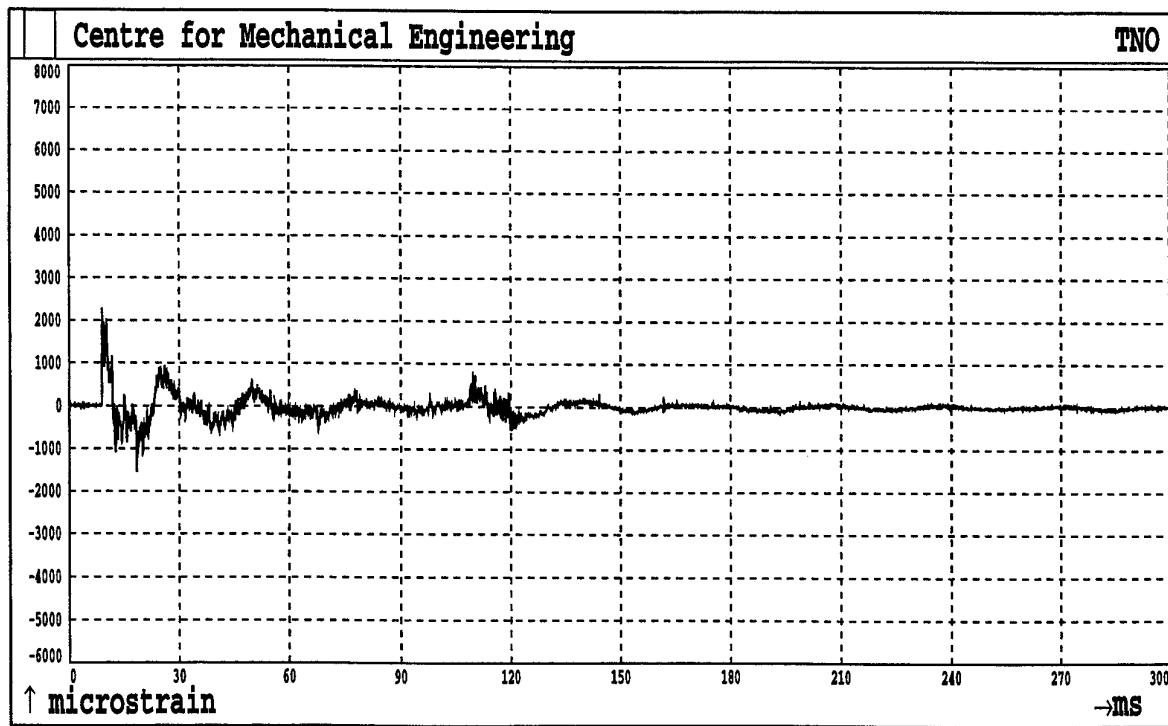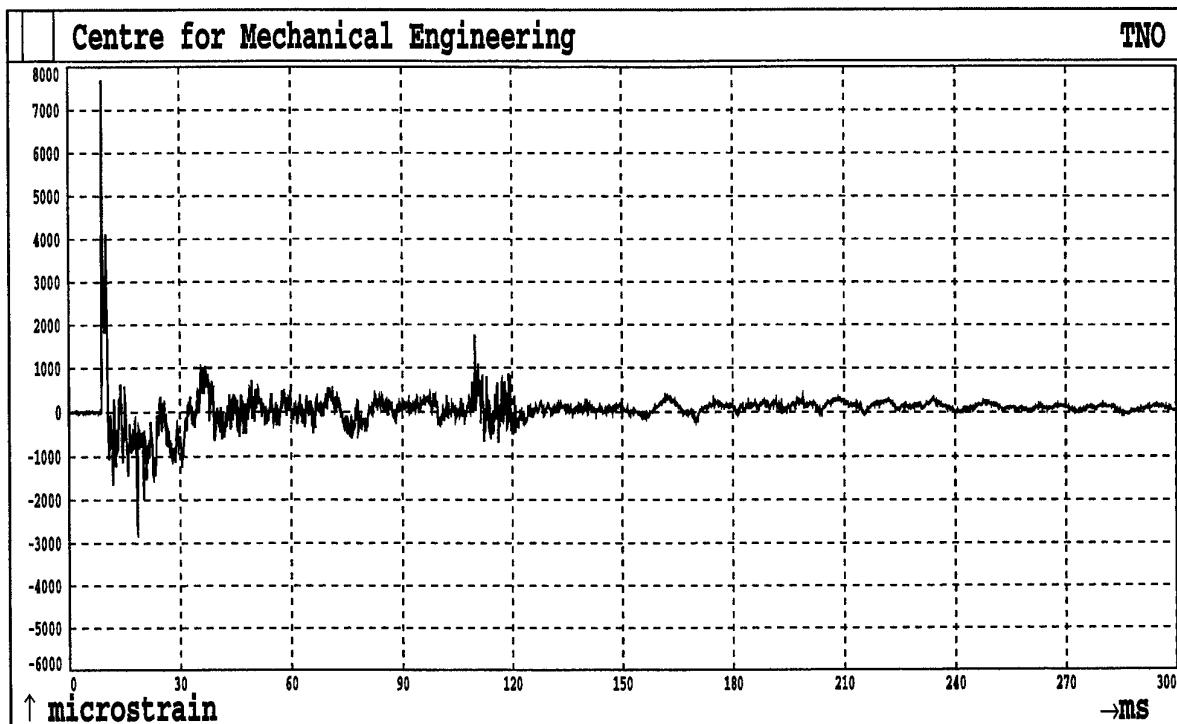
Fig.283. Shot 6   Sensor S17

Fig.284. Shot 6   Sensor S18

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A.145
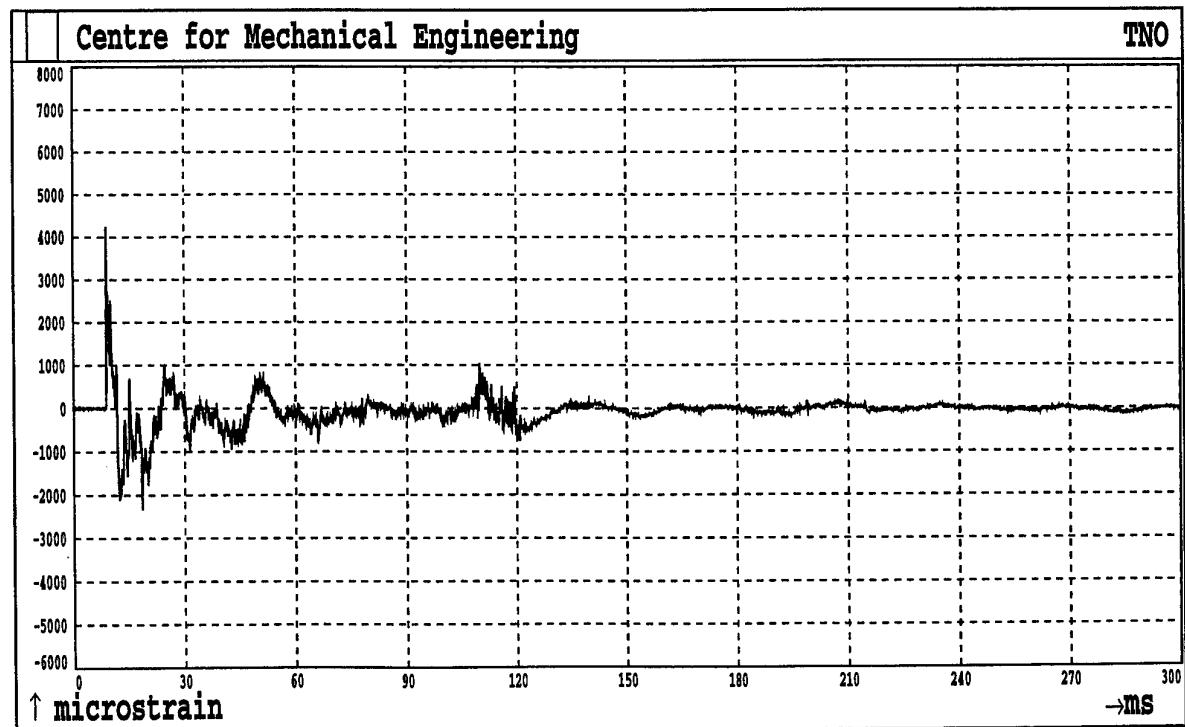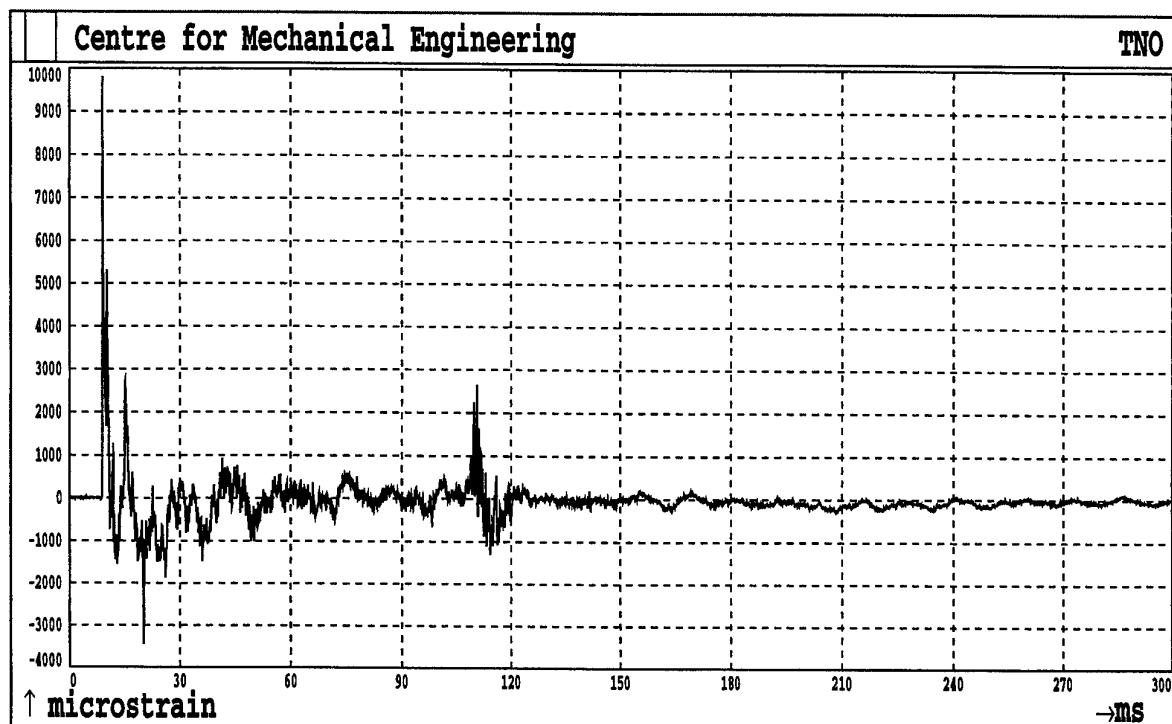
Fig.285. Shot 6   Sensor S19

Fig.286. Shot 6   Sensor S20

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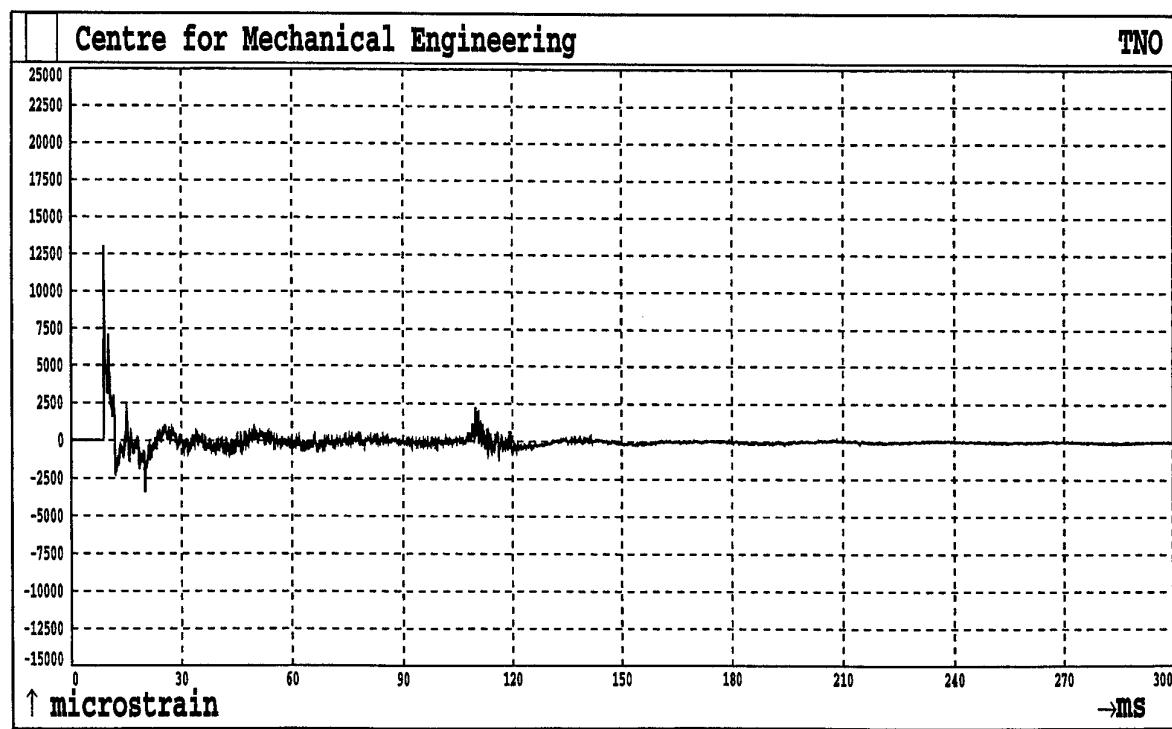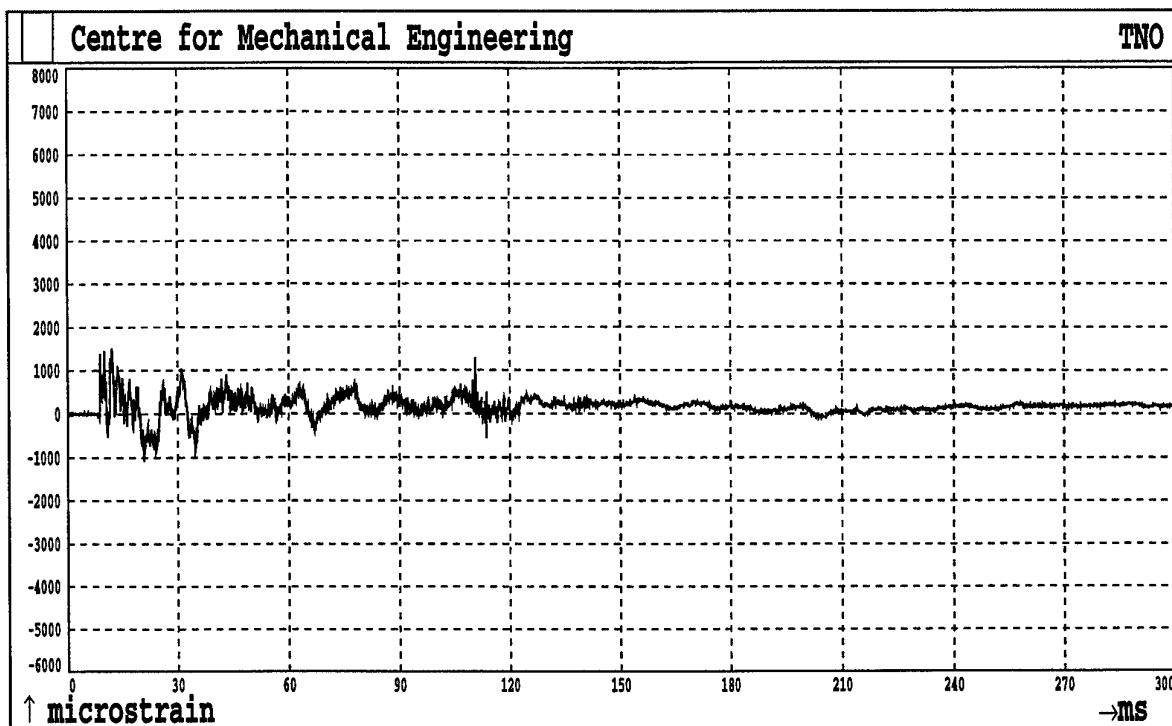
Fig.287. Shot 6 Sensor S21

Fig.288. Shot 6 Sensor S22

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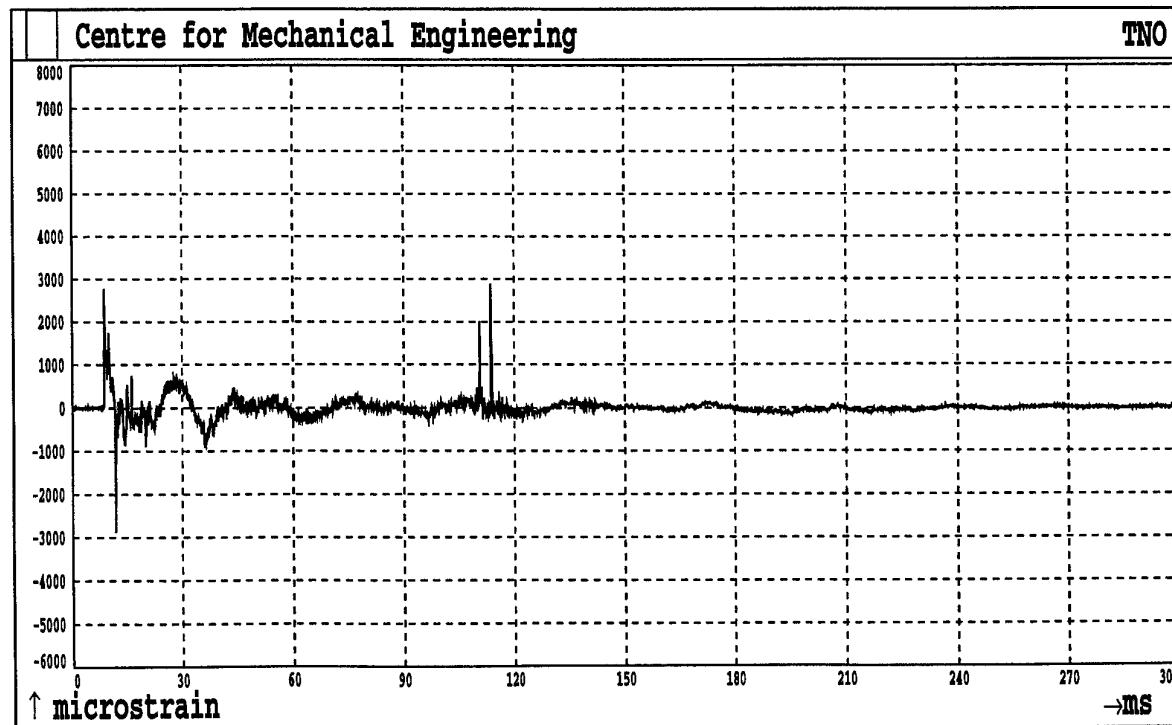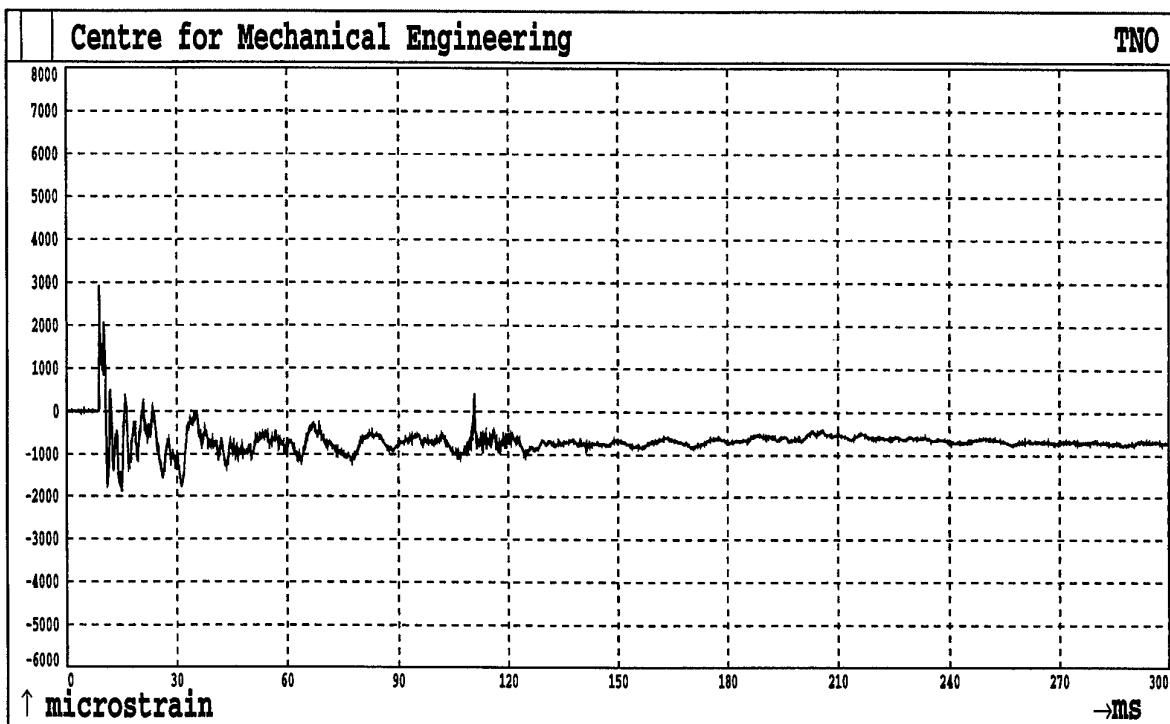
Fig.289. Shot 6   Sensor S23

Fig.290. Shot 6   Sensor S24

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Fig.291. Shot 6   Sensor S25

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Fig.292. Shot 6   Sensor S26

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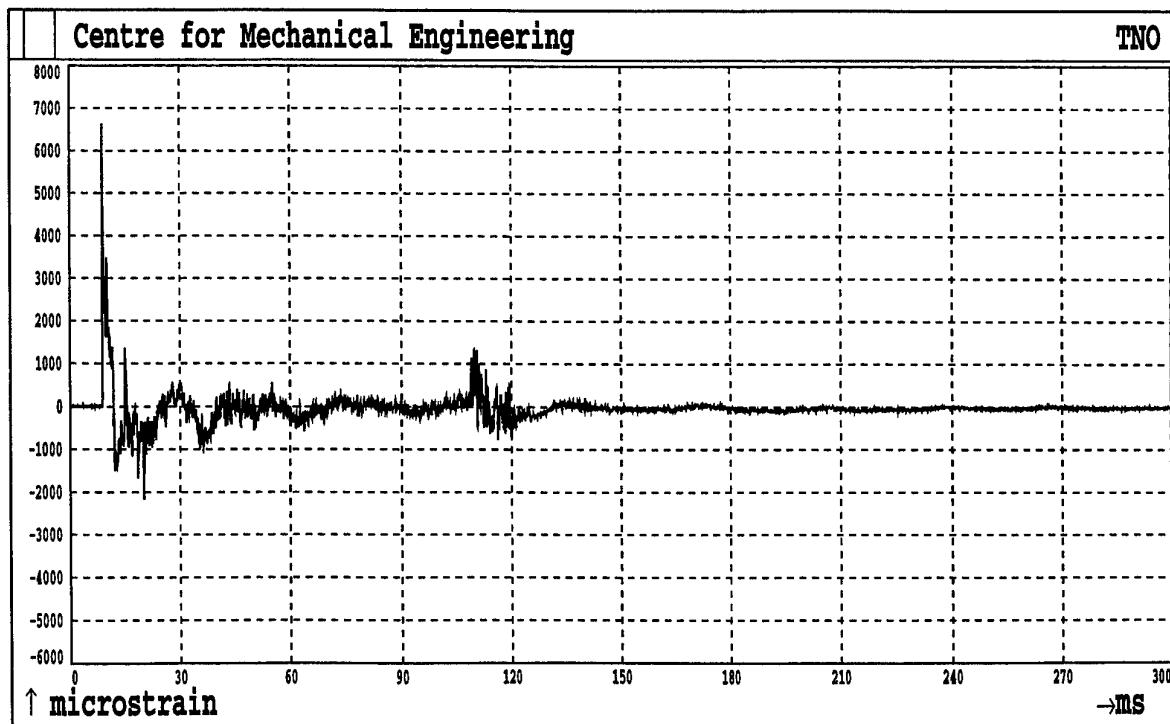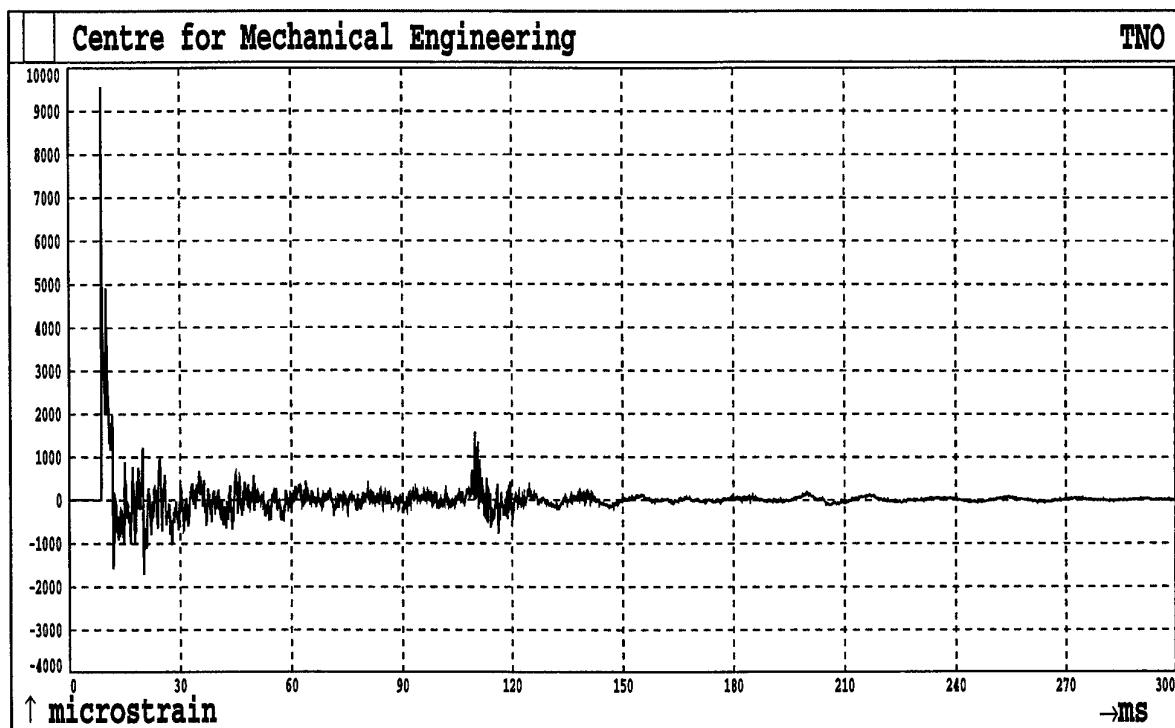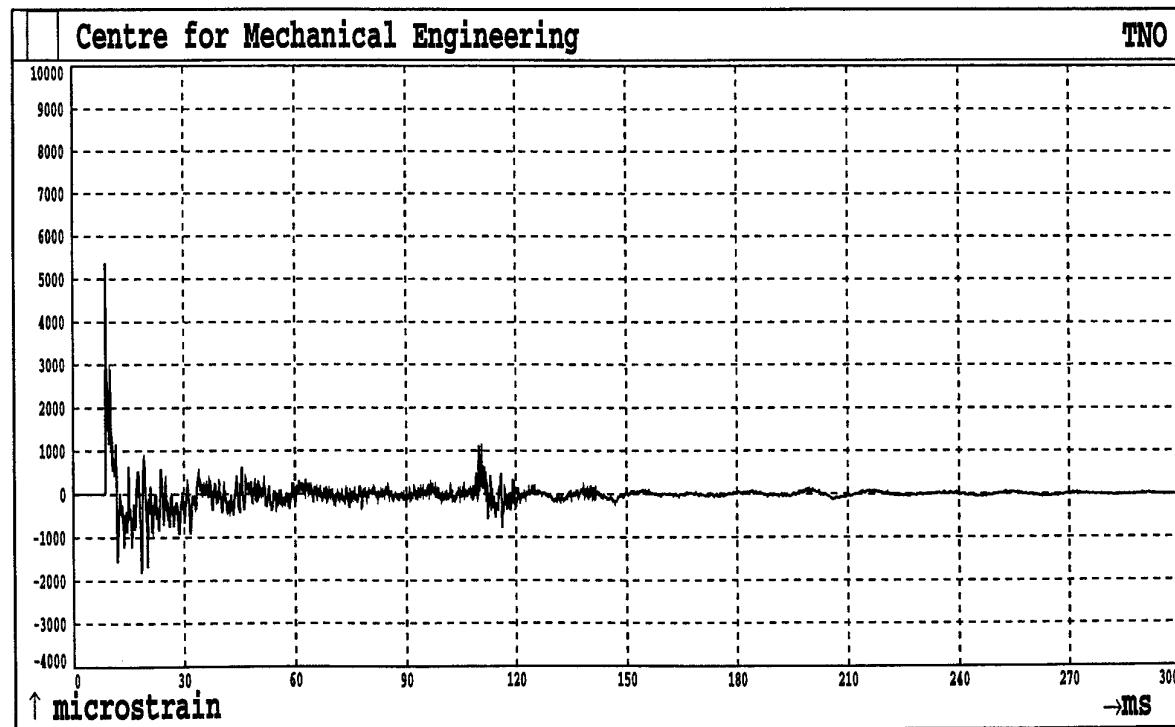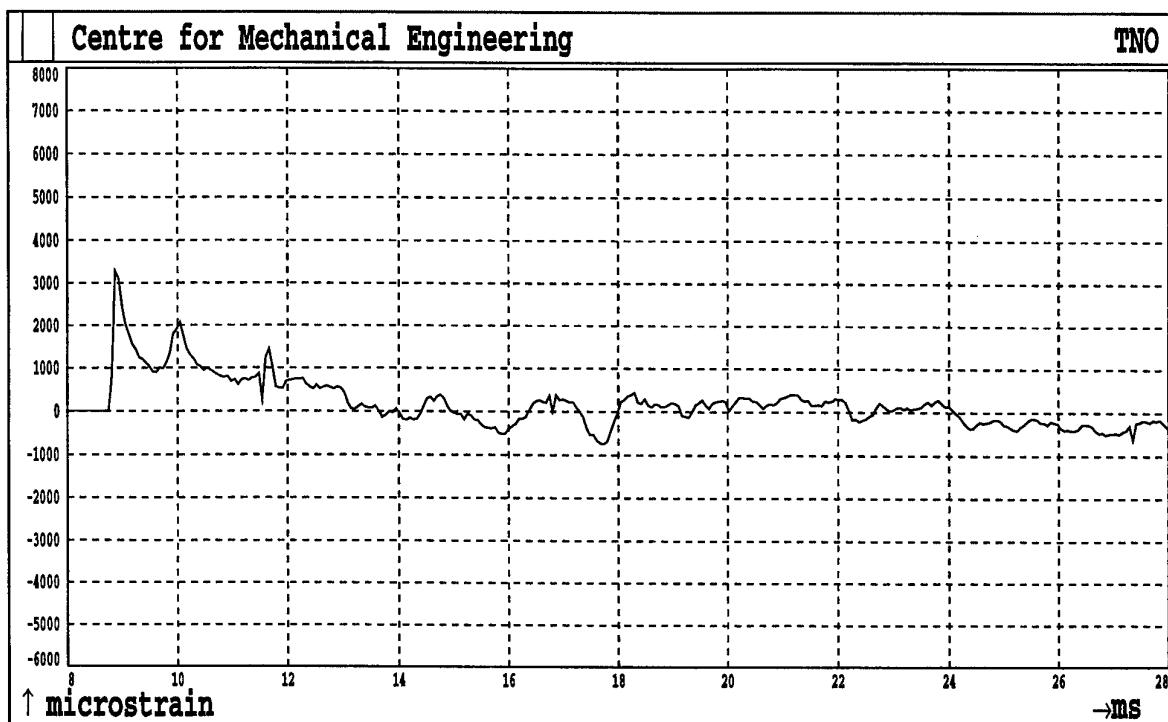
Fig.293. Shot 6   Sensor S1

Fig.294. Shot 6   Sensor S2

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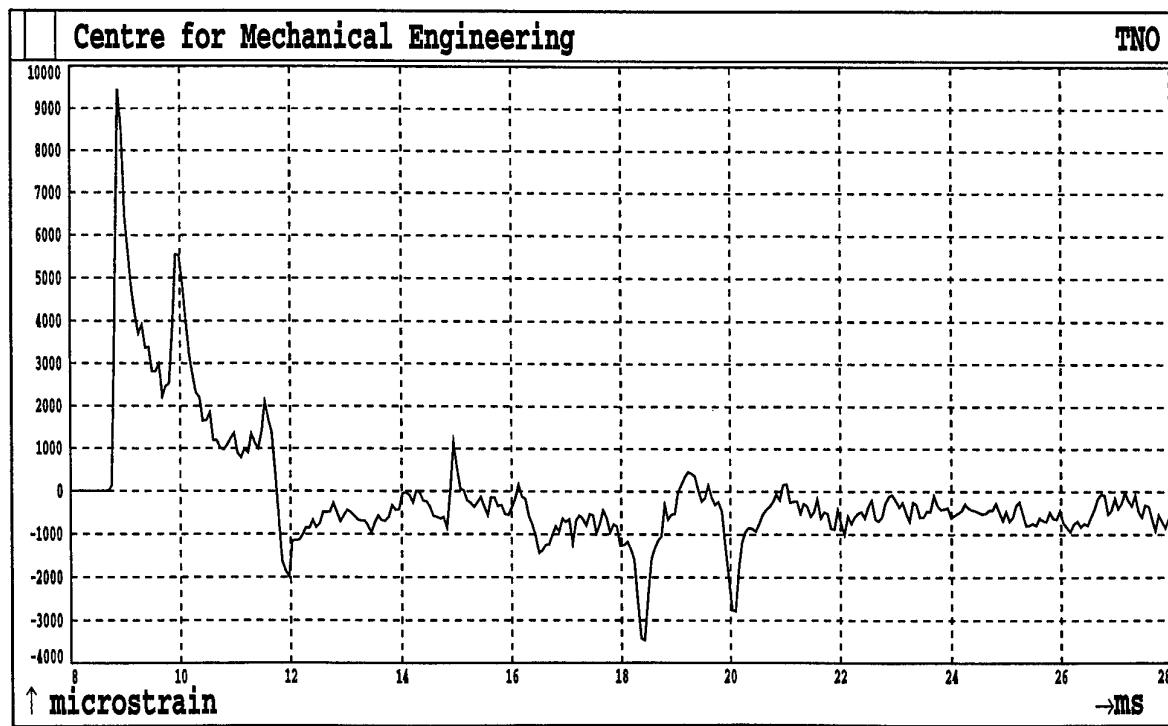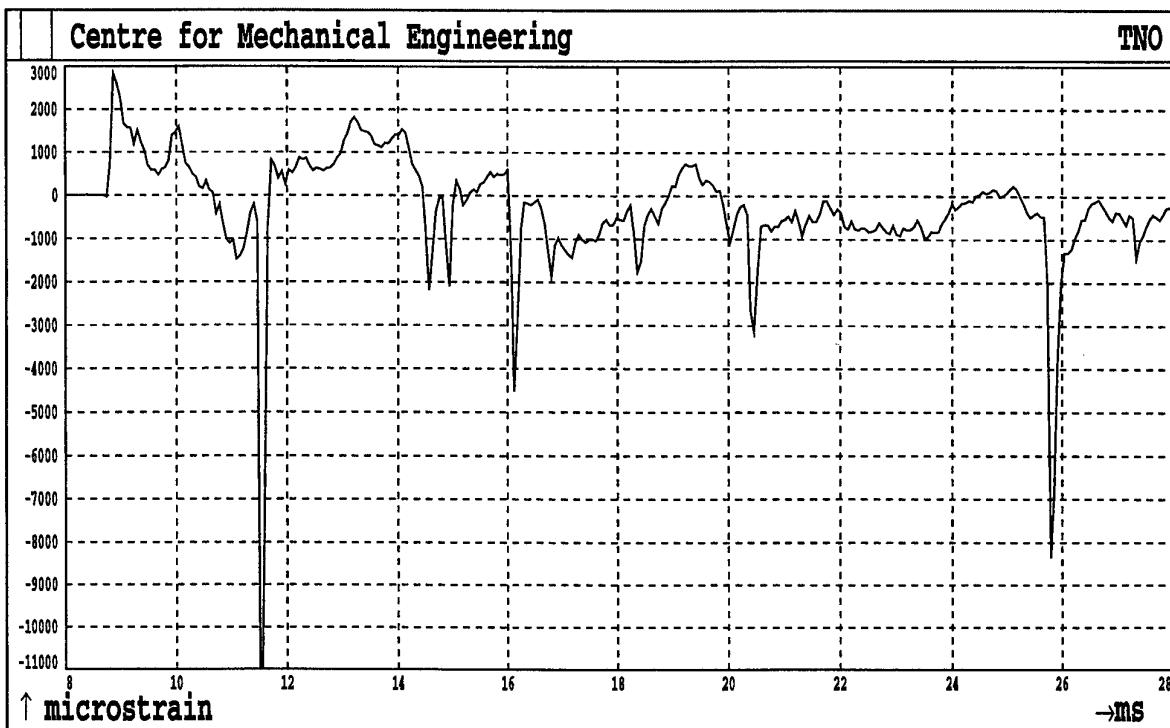
Fig.295. Shot 6   Sensor S3

Fig.296. Shot 6   Sensor S4

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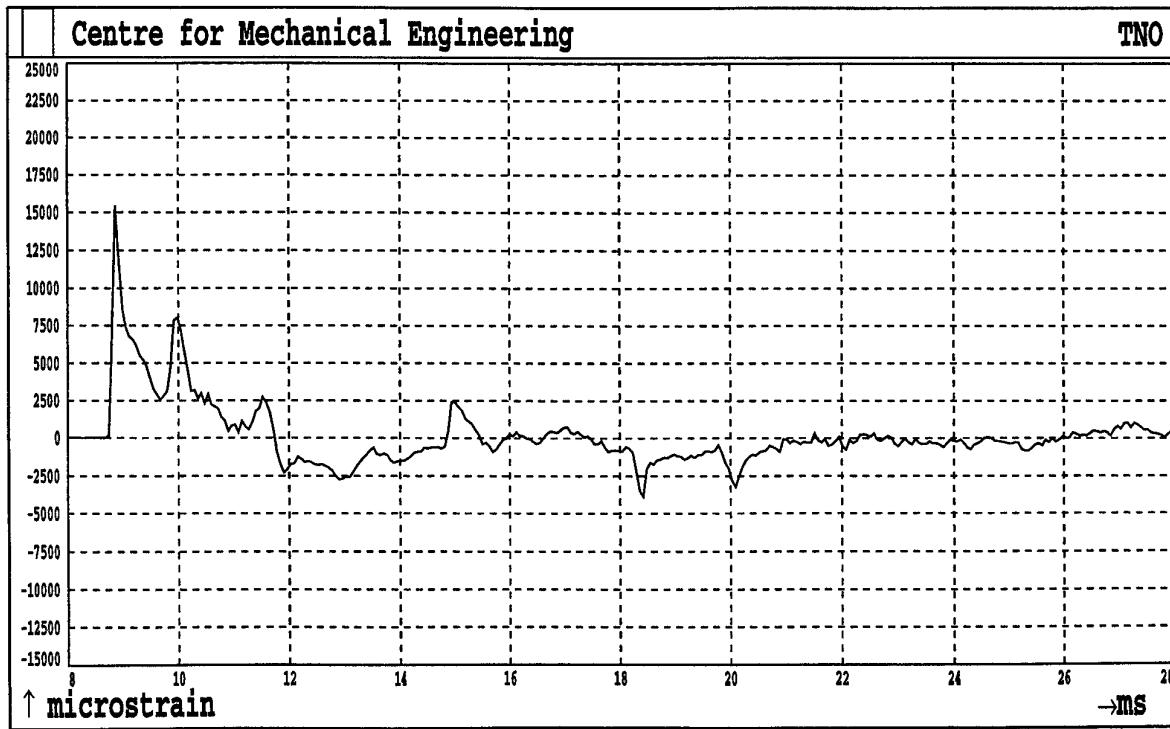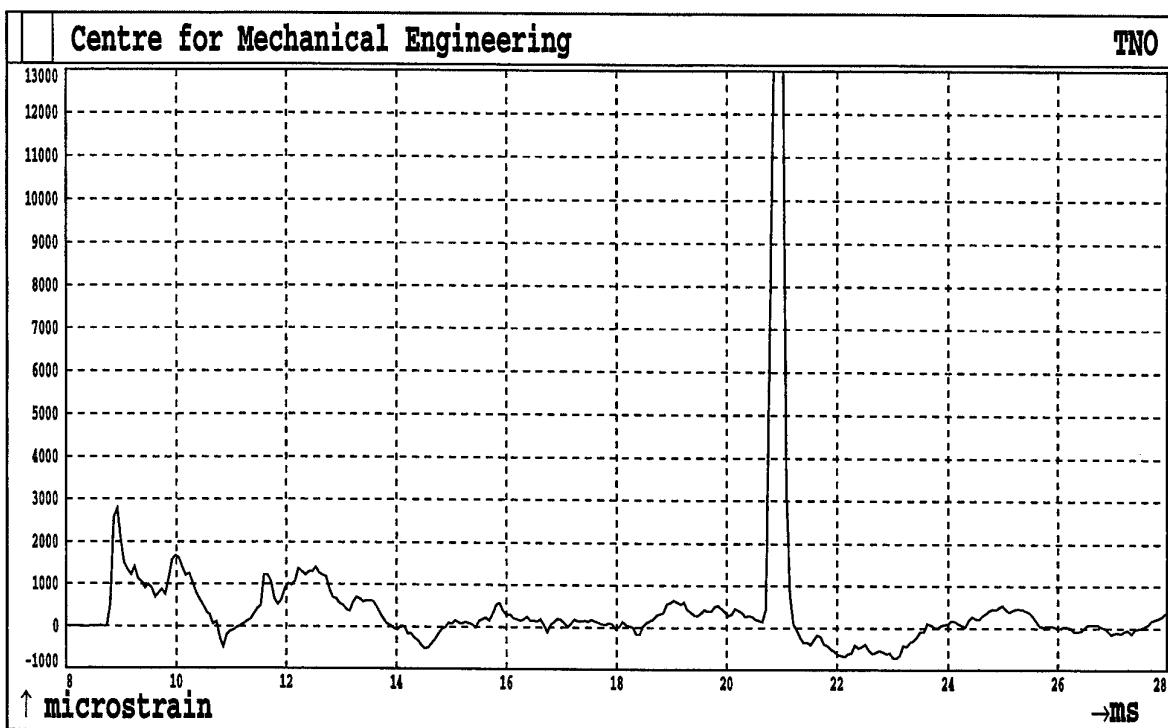
Fig.297. Shot 6 Sensor S5

Fig.298. Shot 6 Sensor S6

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↑ microstrain   →ms

Fig.299. Shot 6   Sensor S7

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↑ microstrain   →ms

Fig.300. Shot 6   Sensor S8

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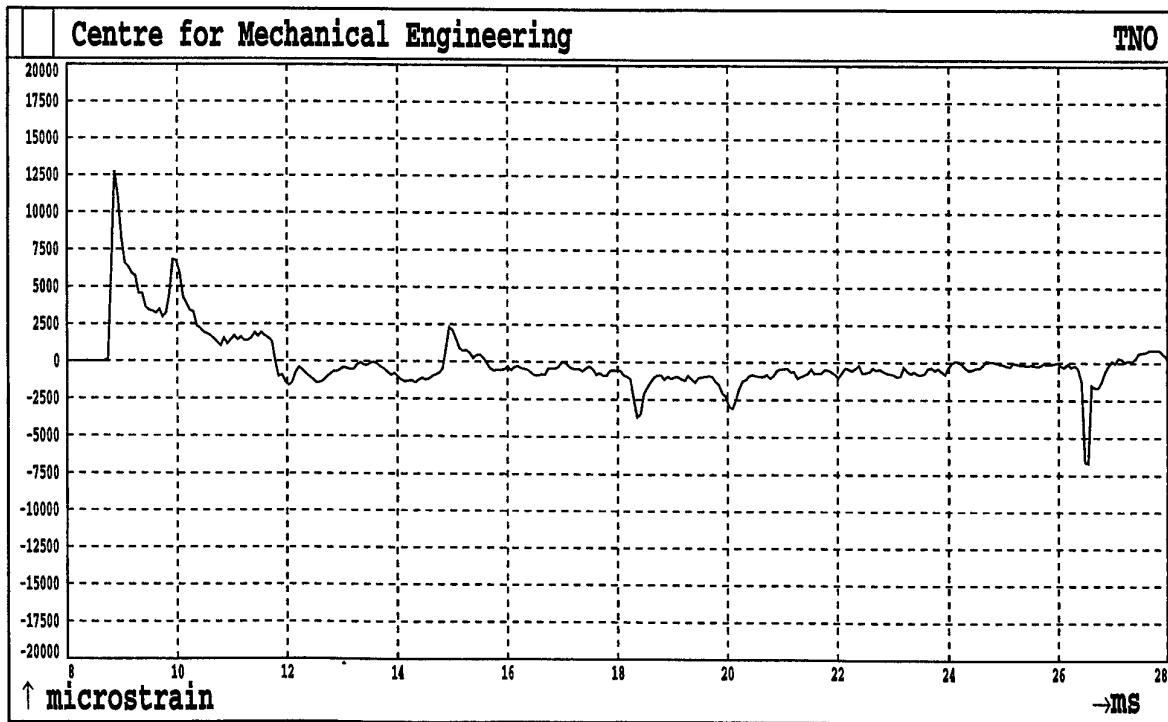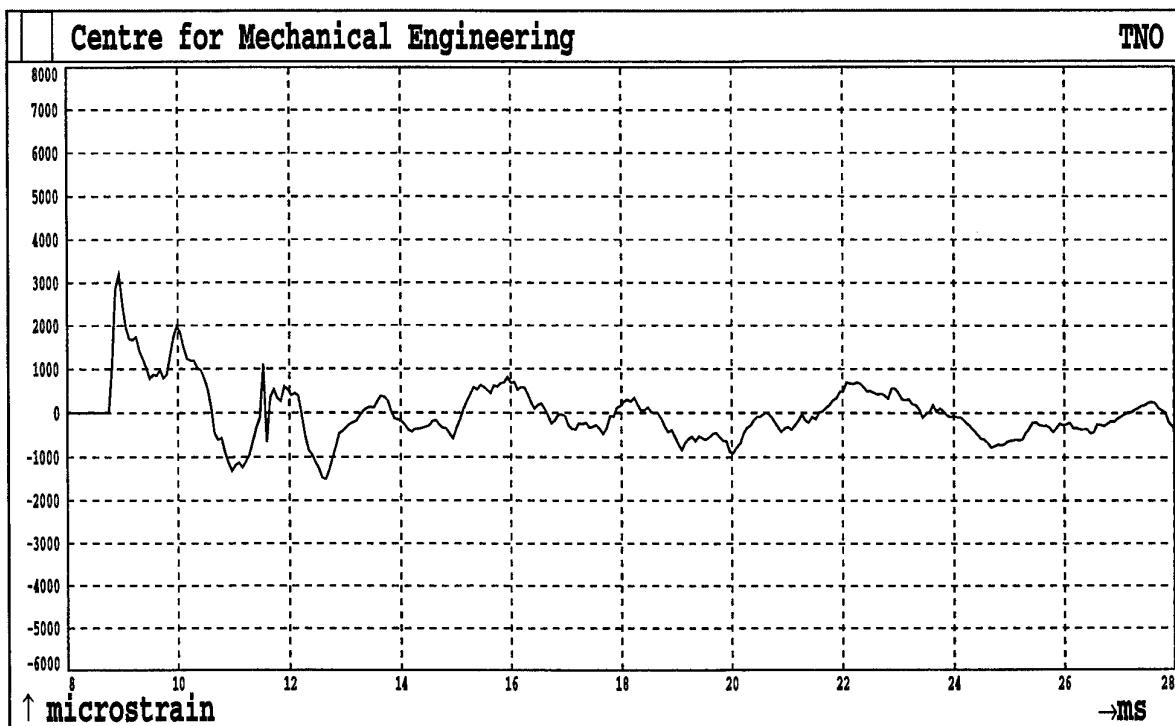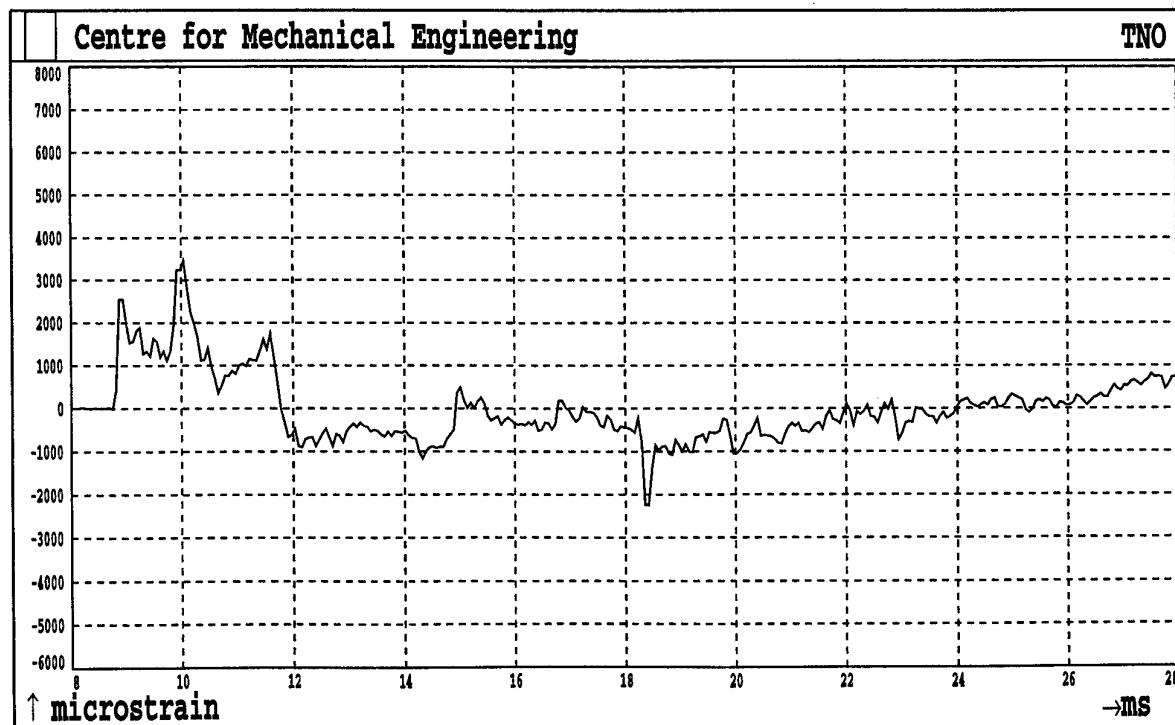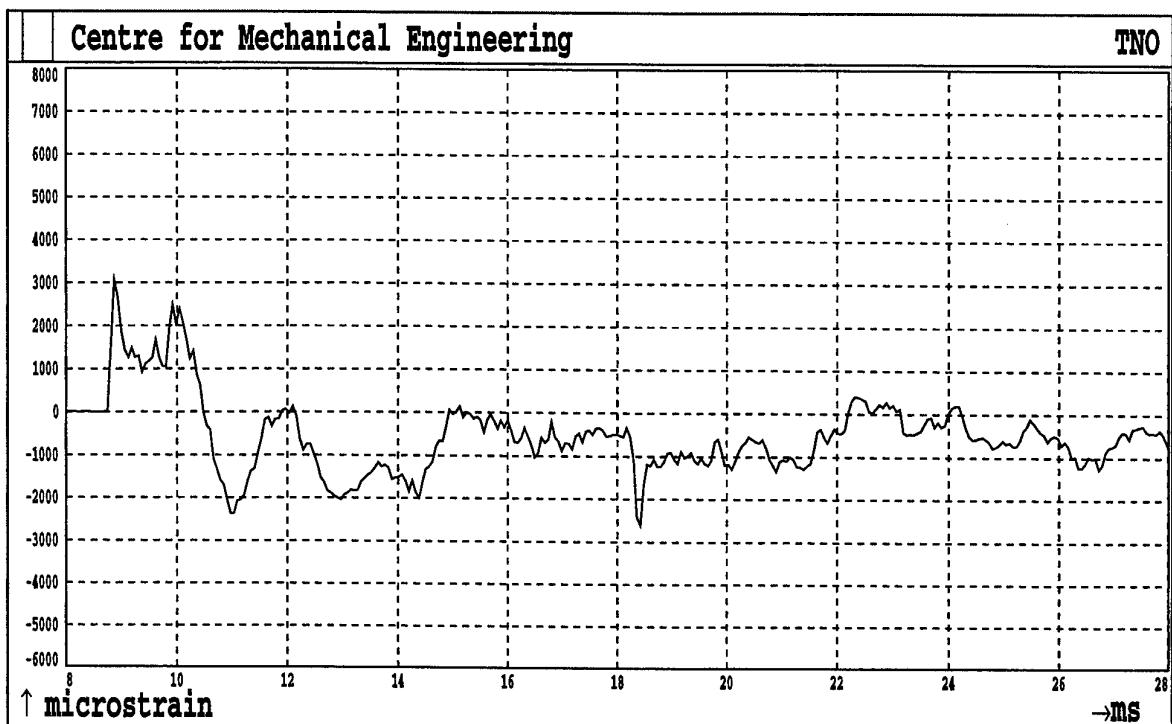
Fig.301. Shot 6   Sensor S11

Fig.302. Shot 6   Sensor S12
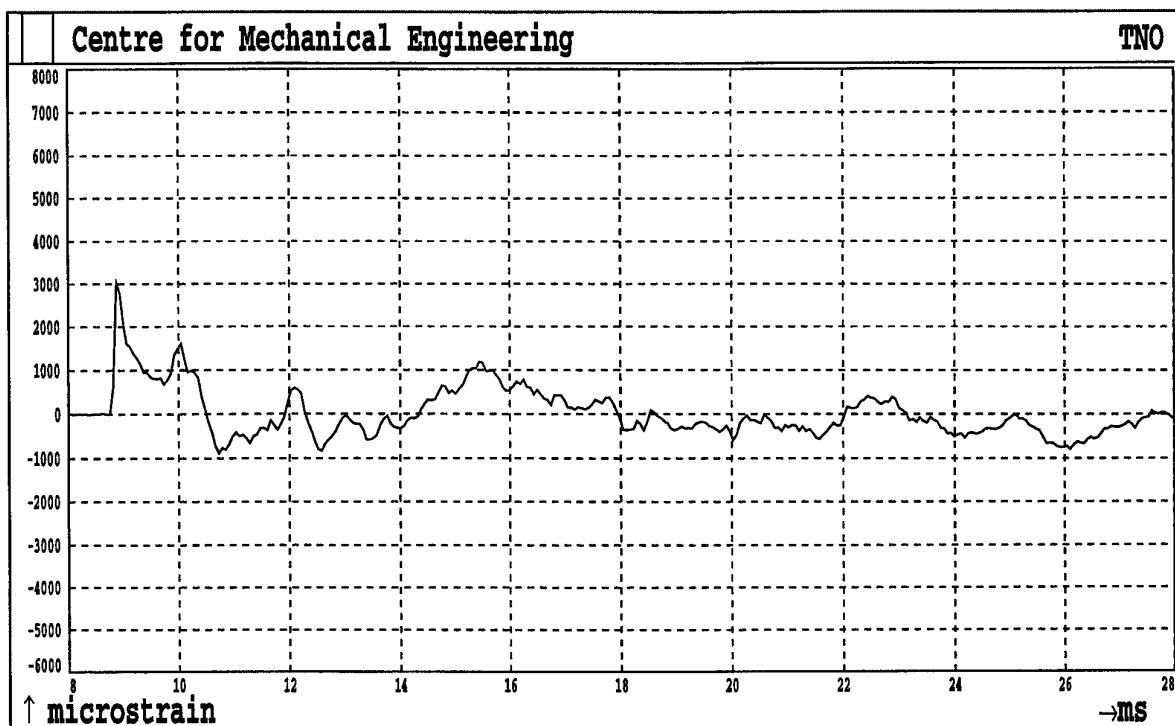
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↑ microstrain   →ms

Fig.303. Shot 6   Sensor S13

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↑ microstrain   →ms

Fig.304. Shot 6   Sensor S14

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Fig.305. Shot 6   Sensor S15

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Fig.306. Shot 6   Sensor S16

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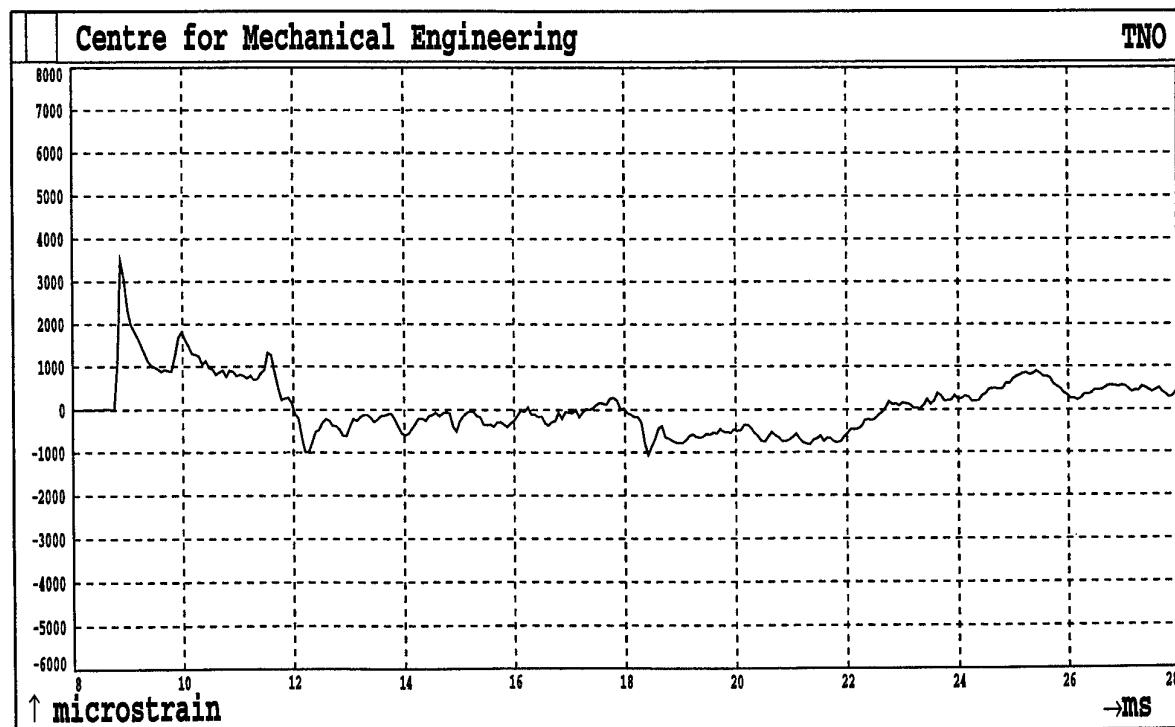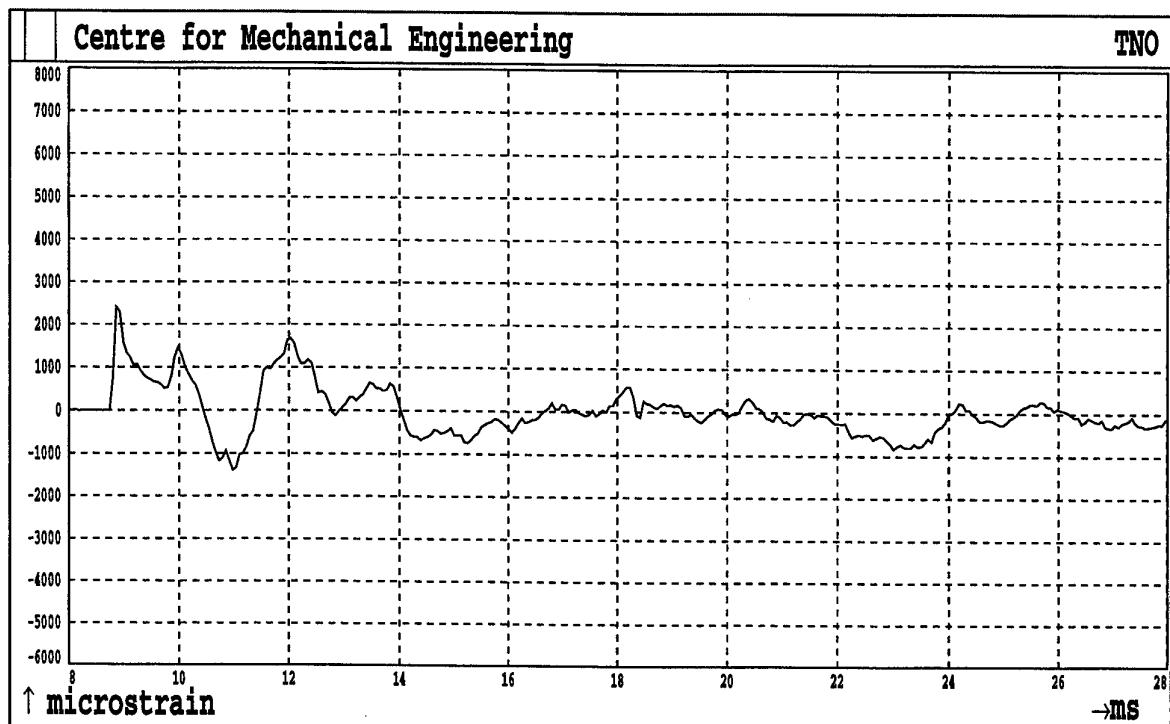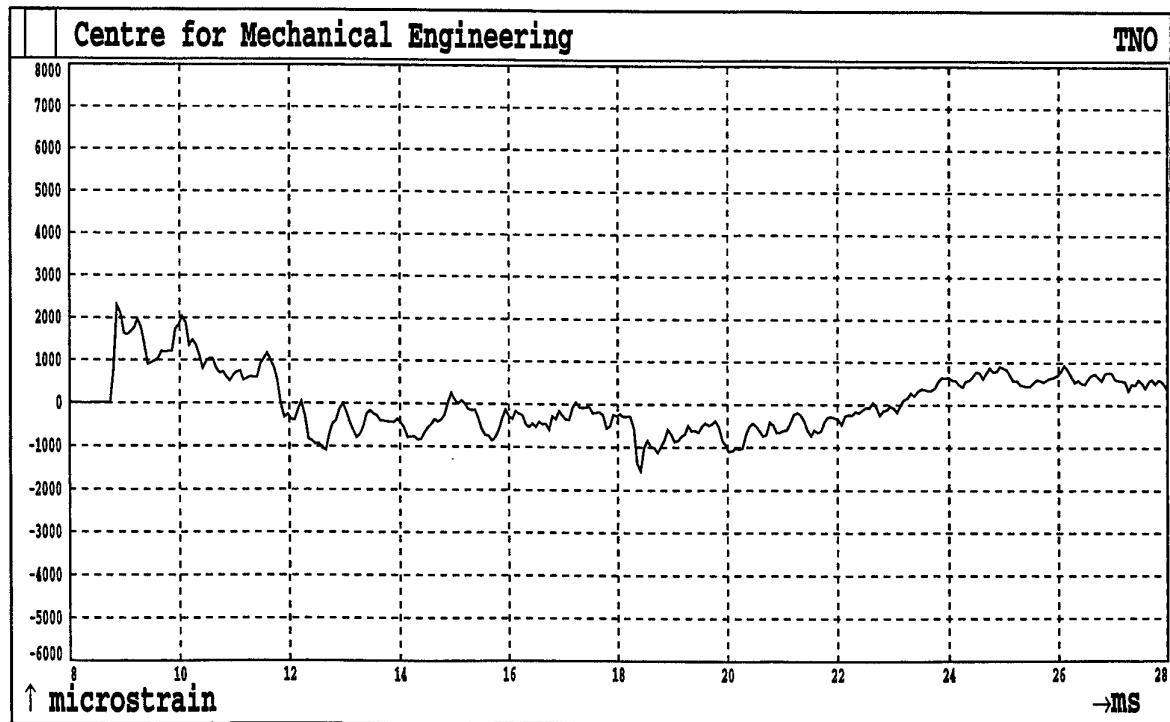
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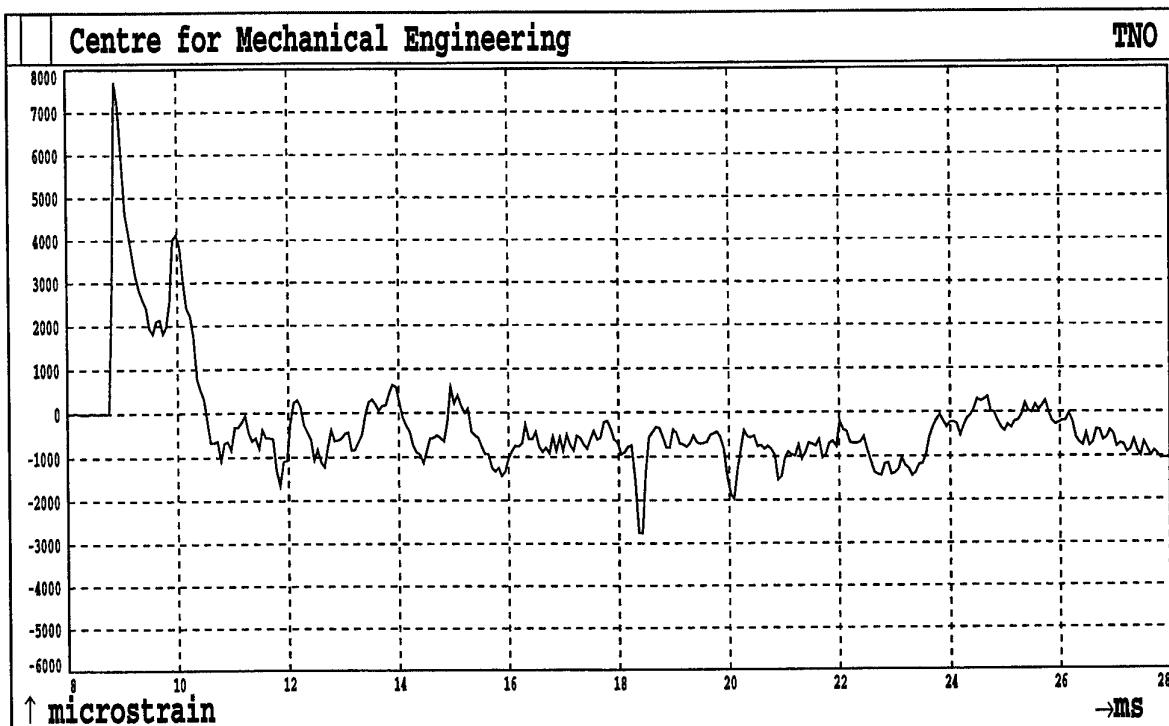
Fig.307. Shot 6   Sensor S17

Fig.308. Shot 6   Sensor S18

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A.157
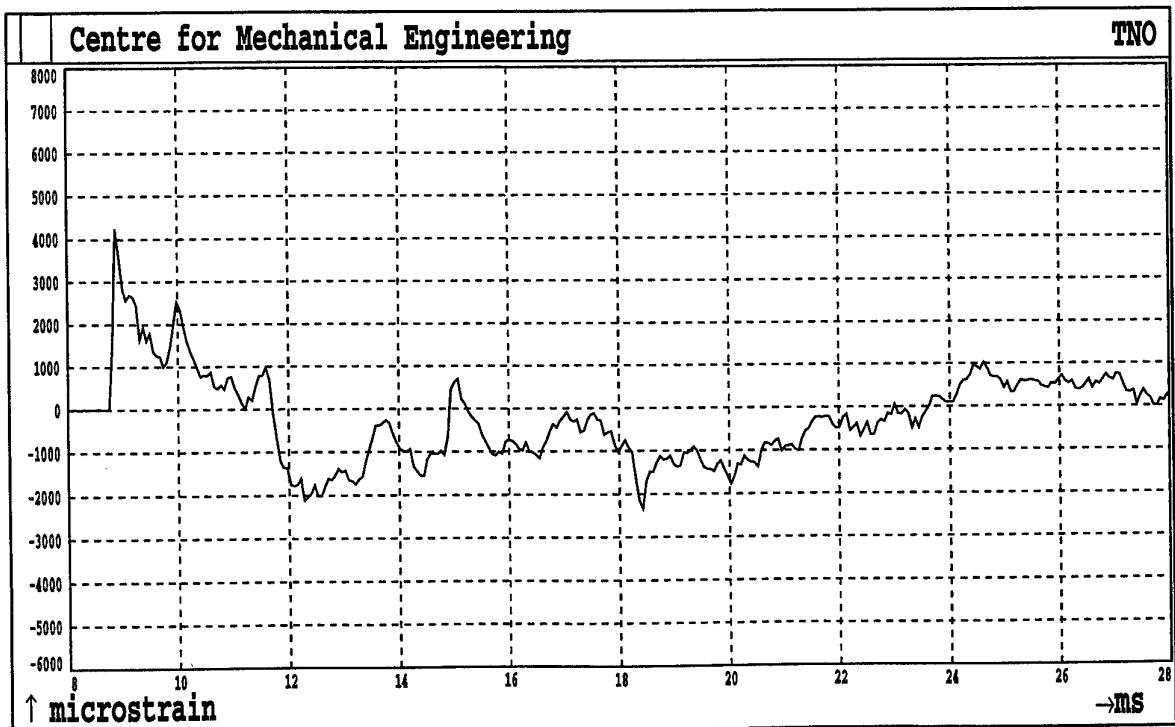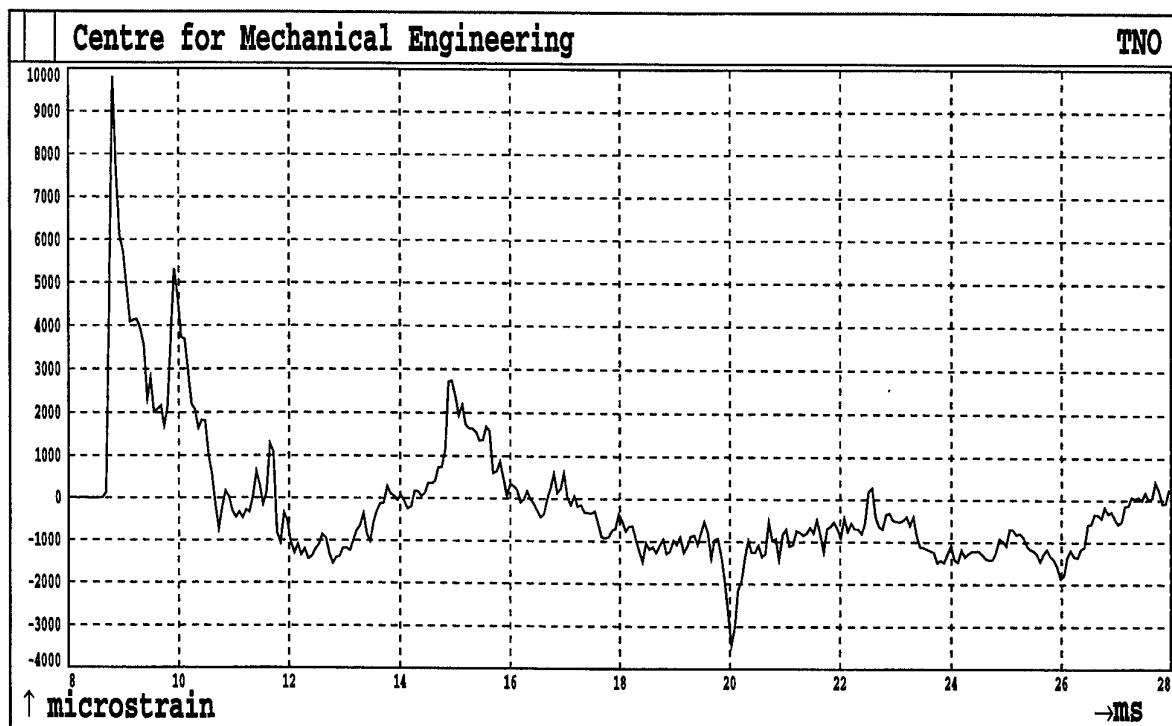
Fig.309. Shot 6   Sensor S19

Fig.310. Shot 6   Sensor S20

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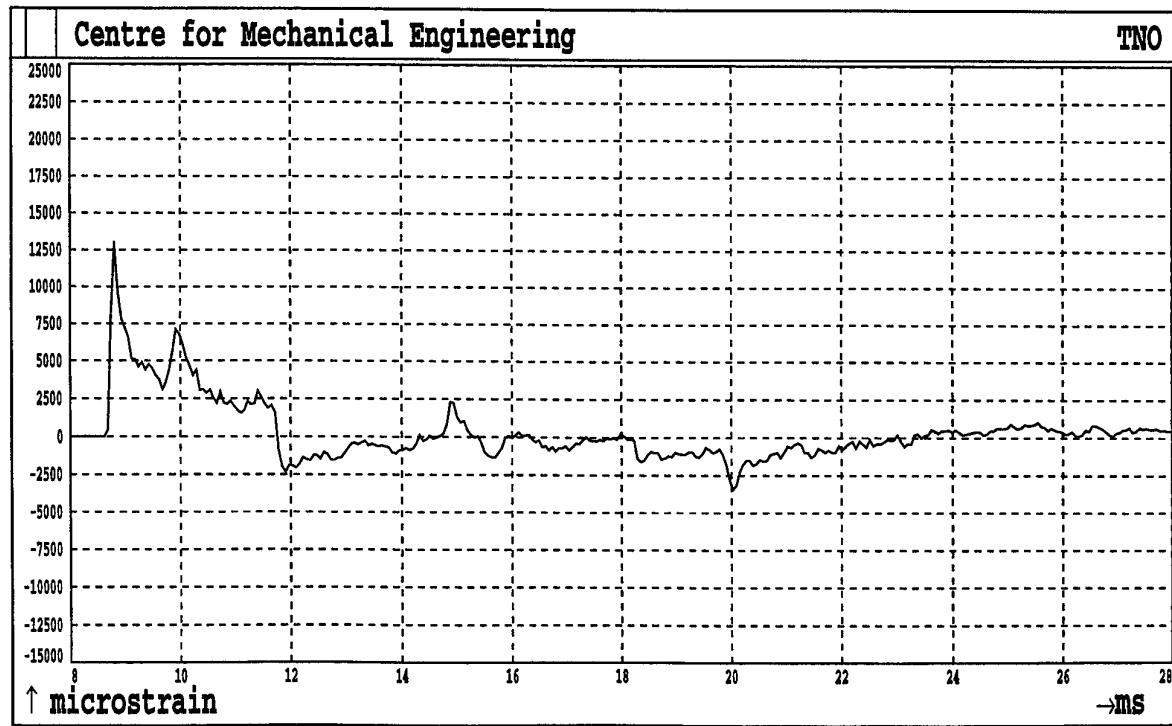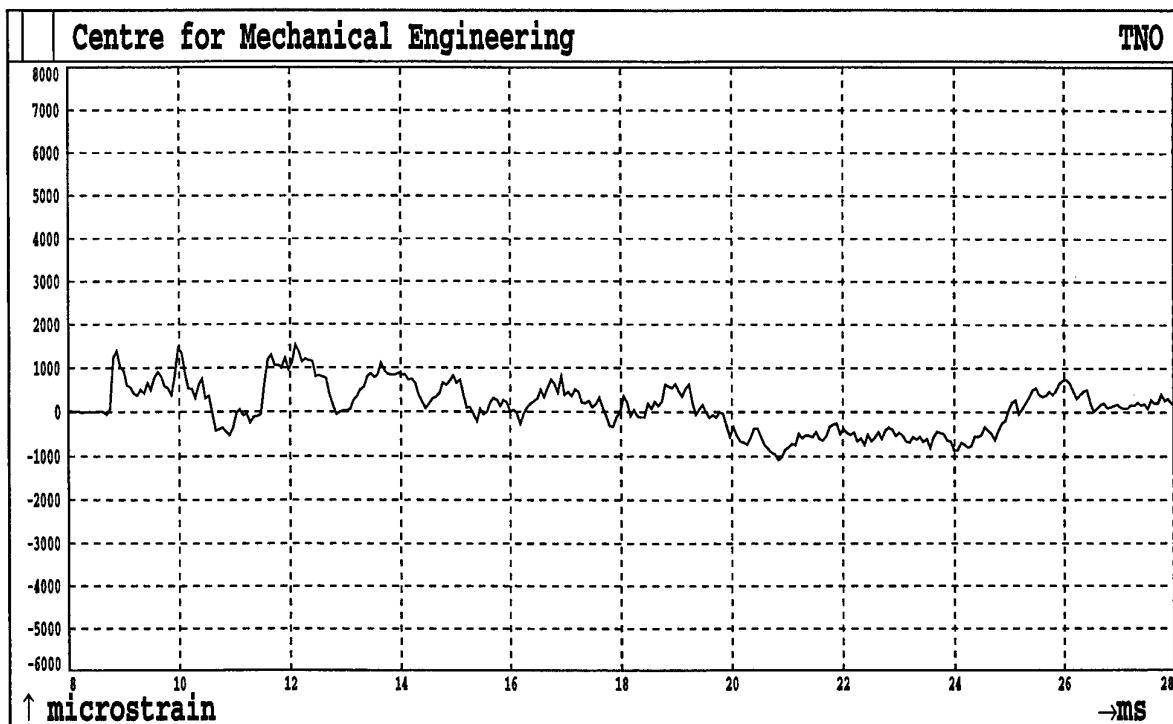
Fig.311. Shot 6   Sensor S21
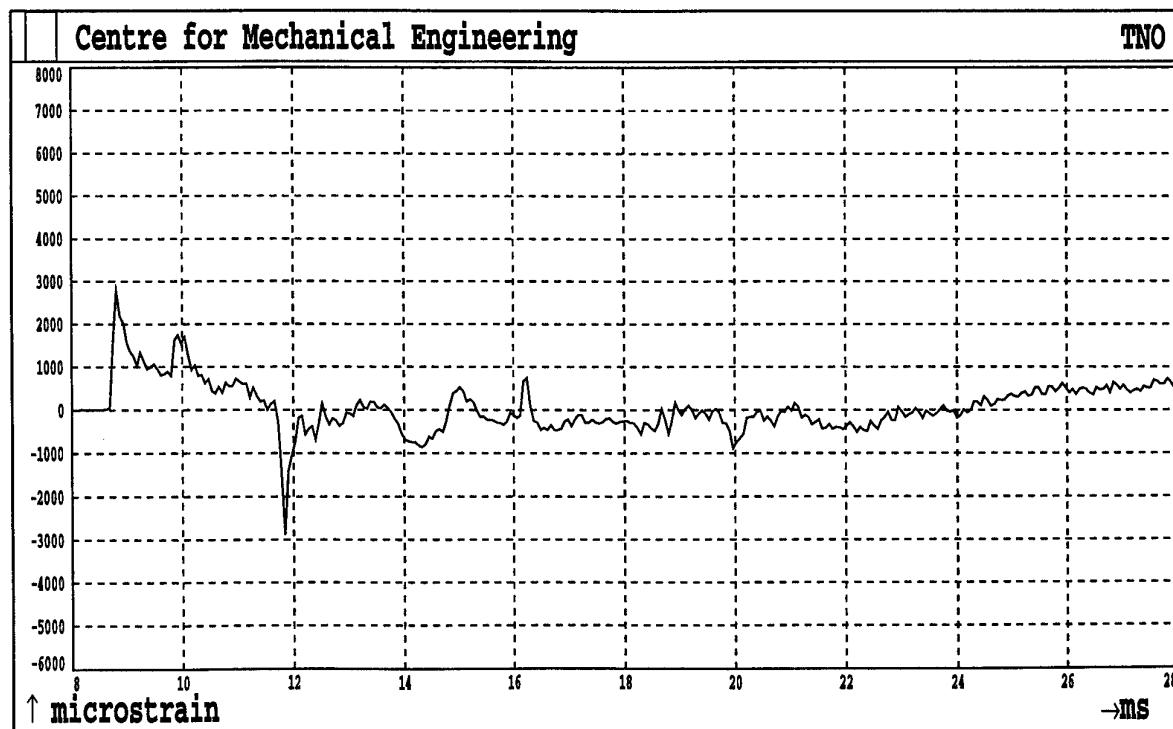
Fig.312. Shot 6   Sensor S22
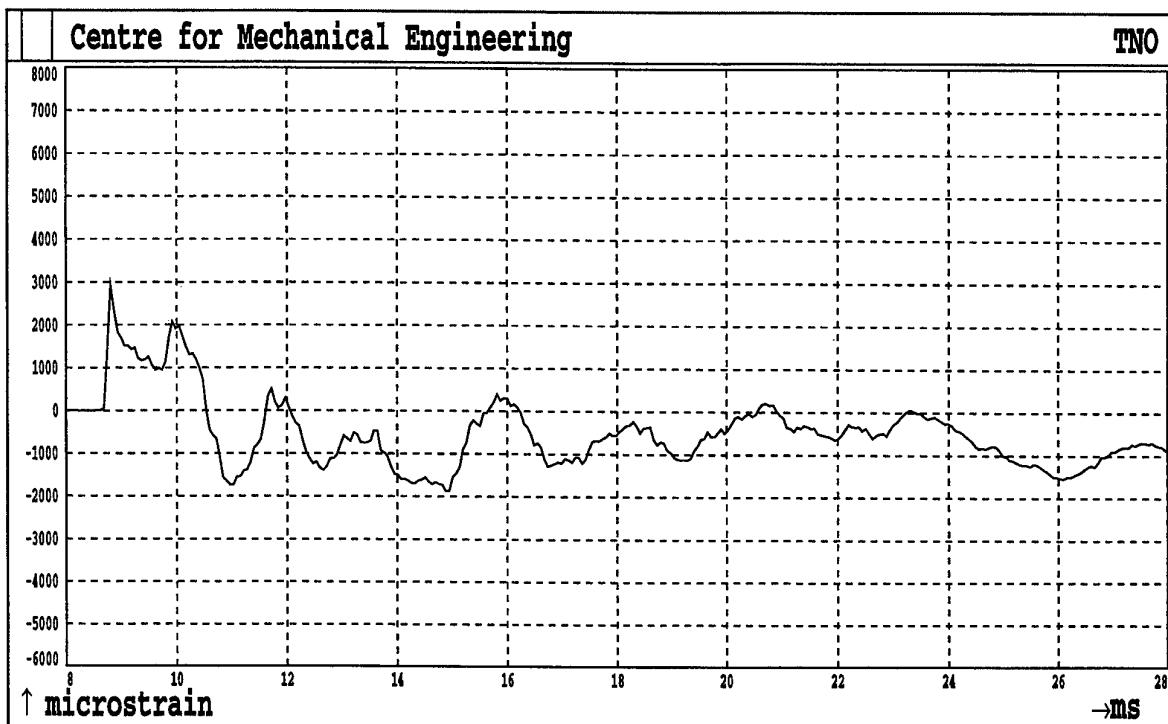
Fig.313. Shot 6   Sensor S23

Fig.314. Shot 6   Sensor S24

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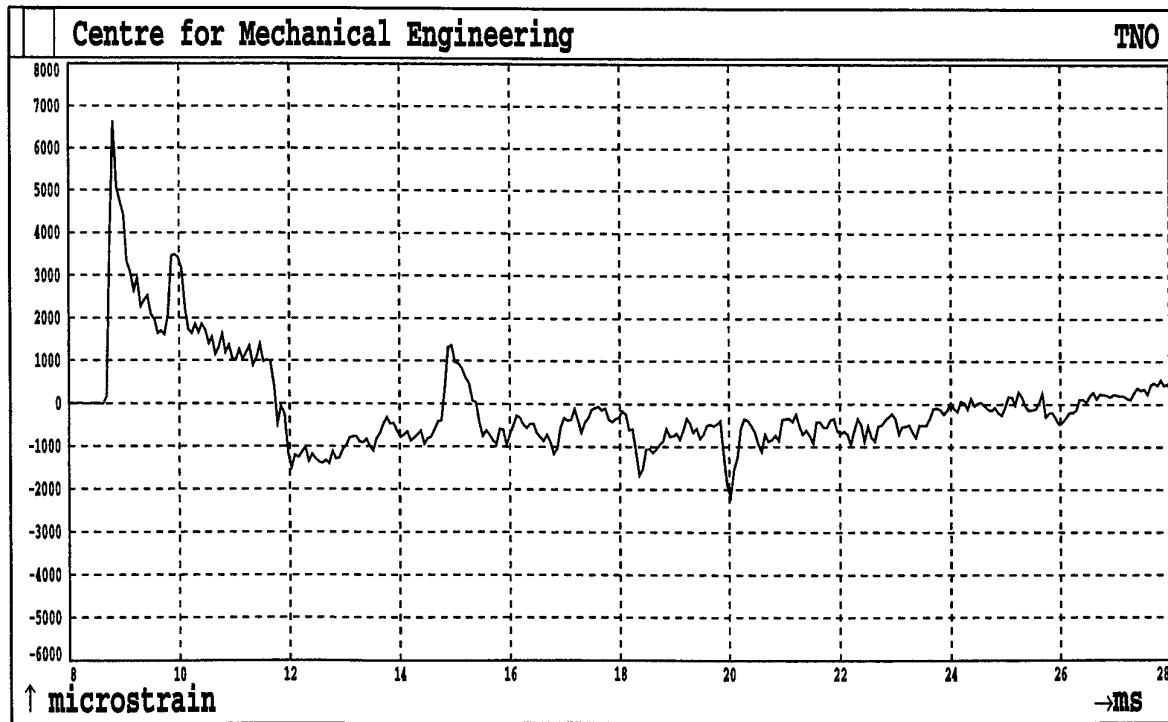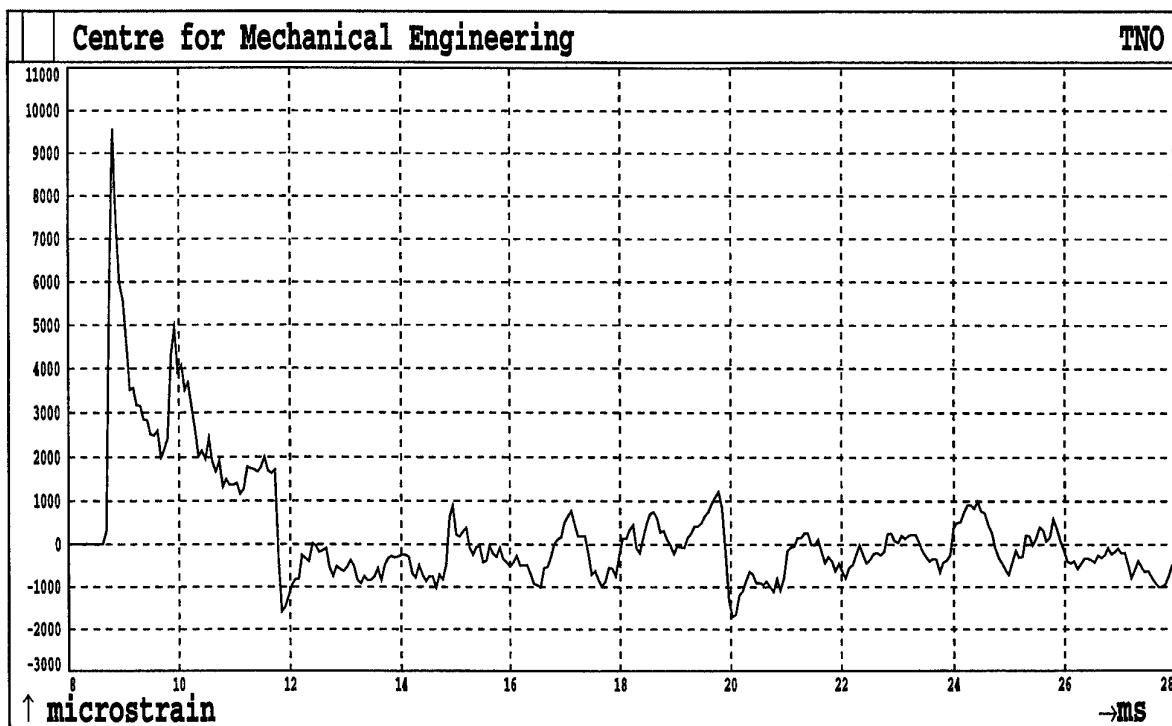
Fig.315. Shot 6   Sensor S25

Fig.316. Shot 6   Sensor S26

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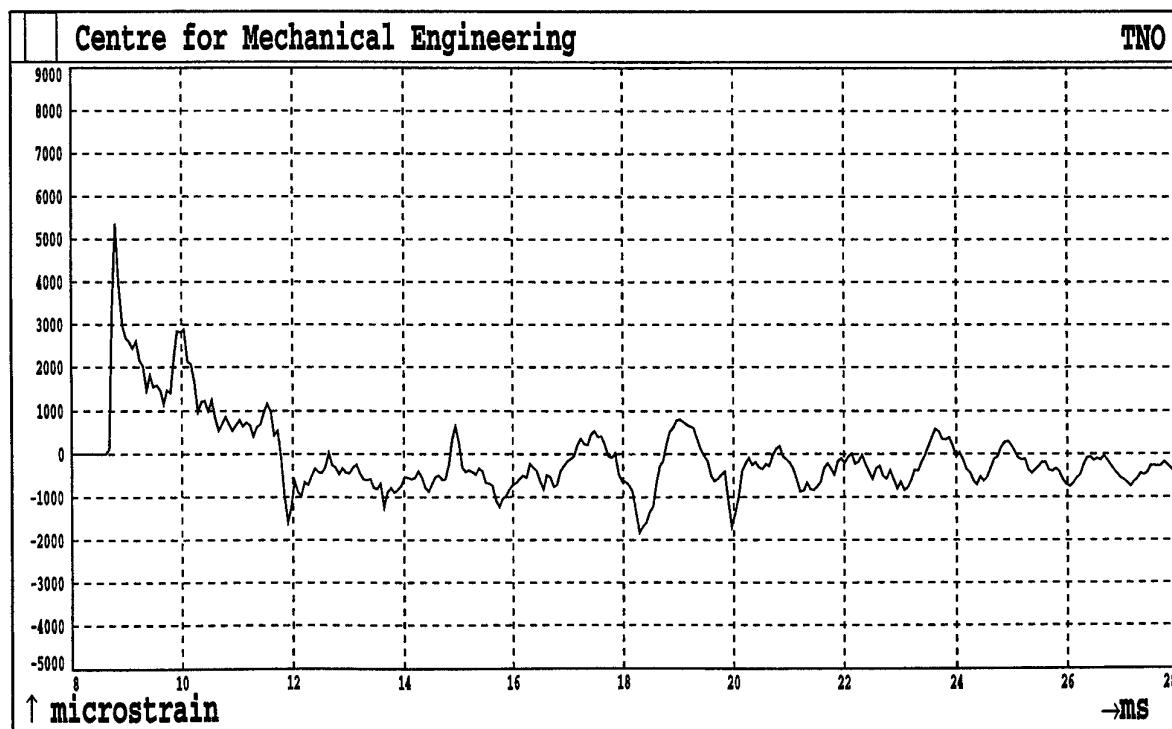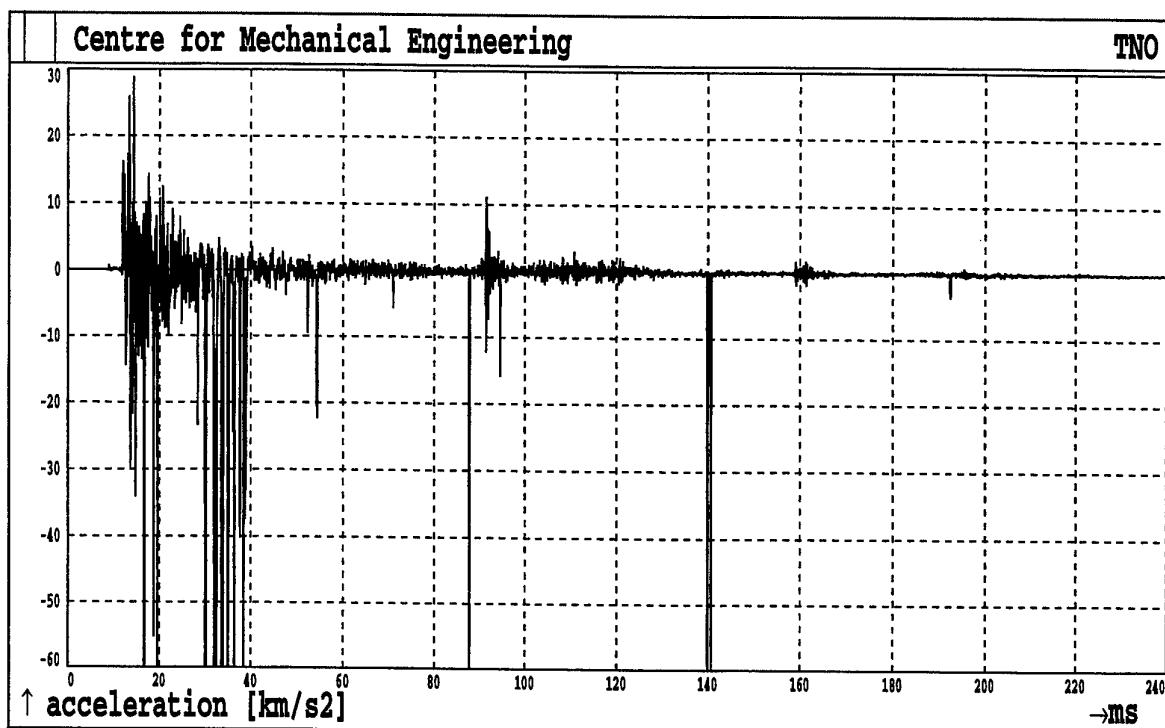
Fig.317. Shot 6   Sensor A2

Fig.318. Shot 6   Sensor A5

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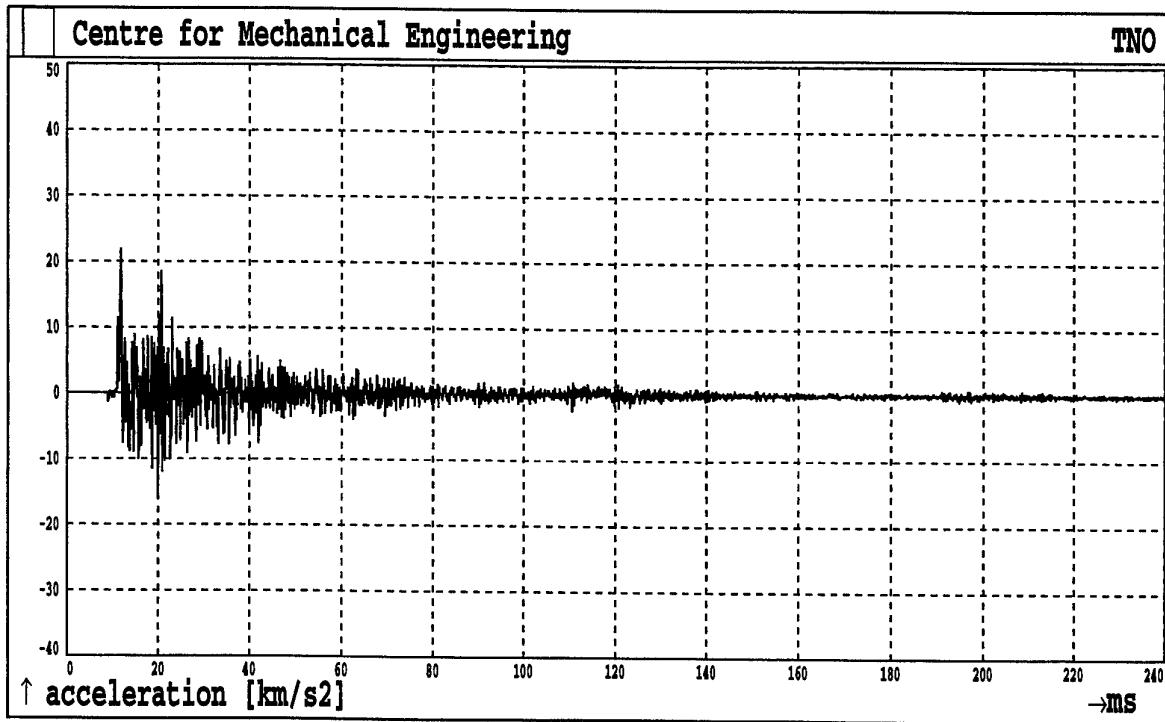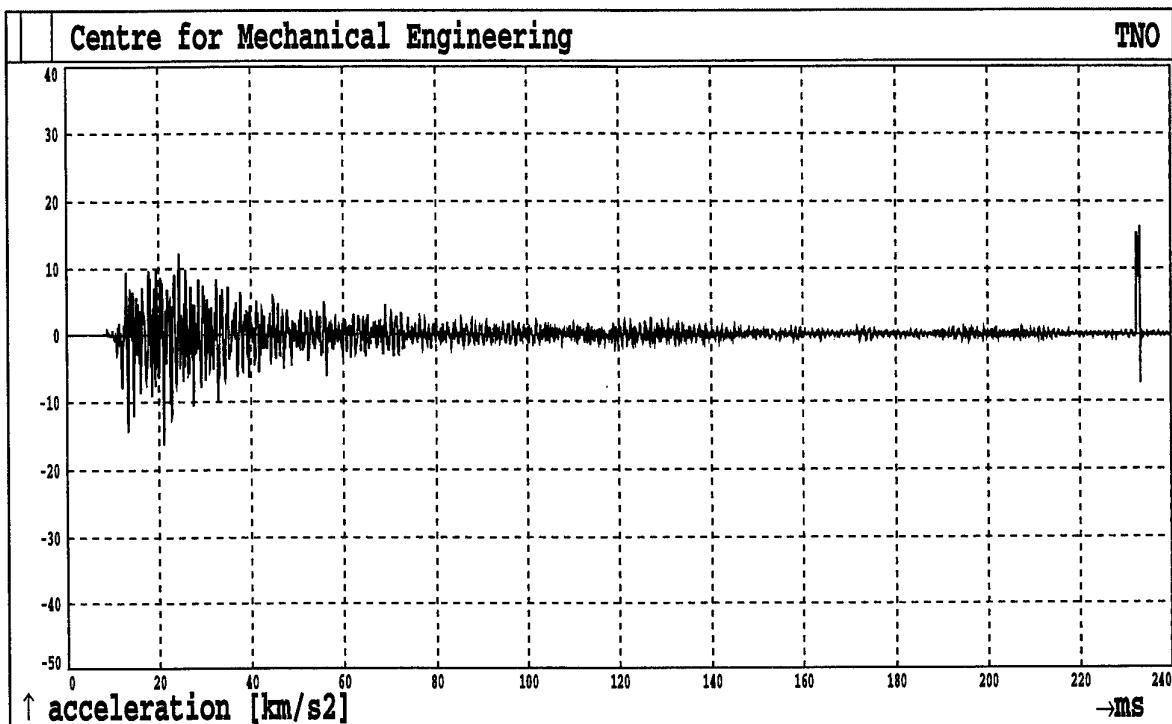
Fig.319. Shot 6   Sensor A6

Fig.320. Shot 6   Sensor A8

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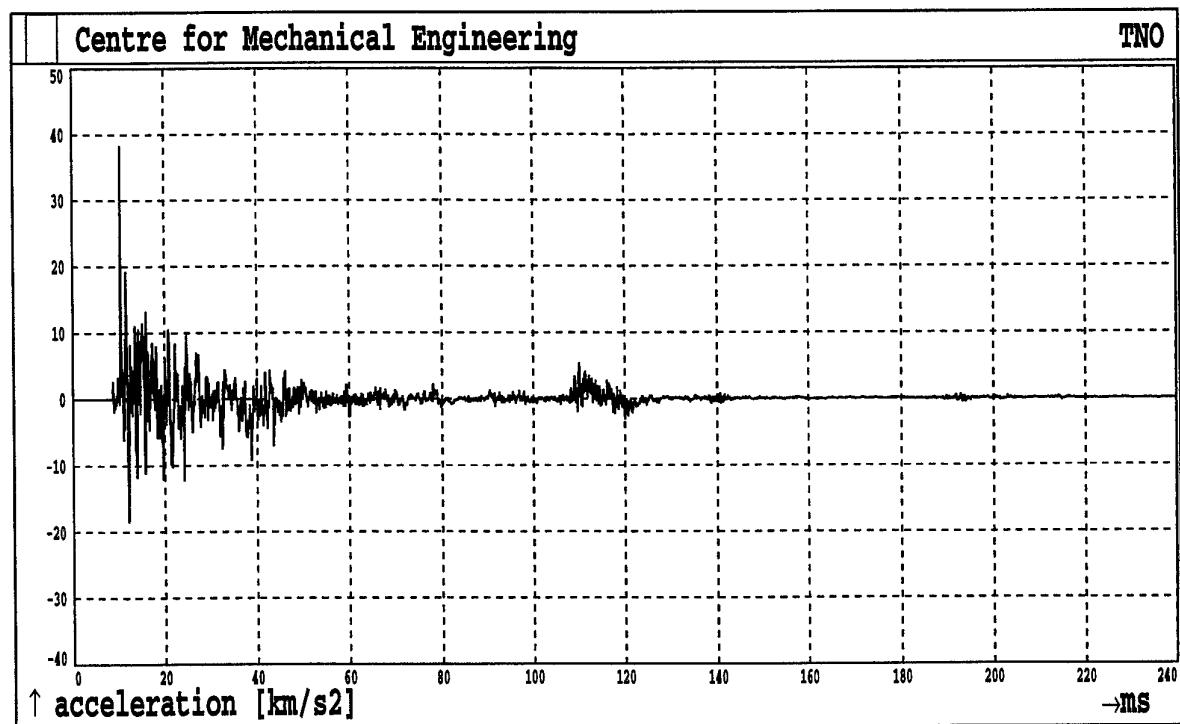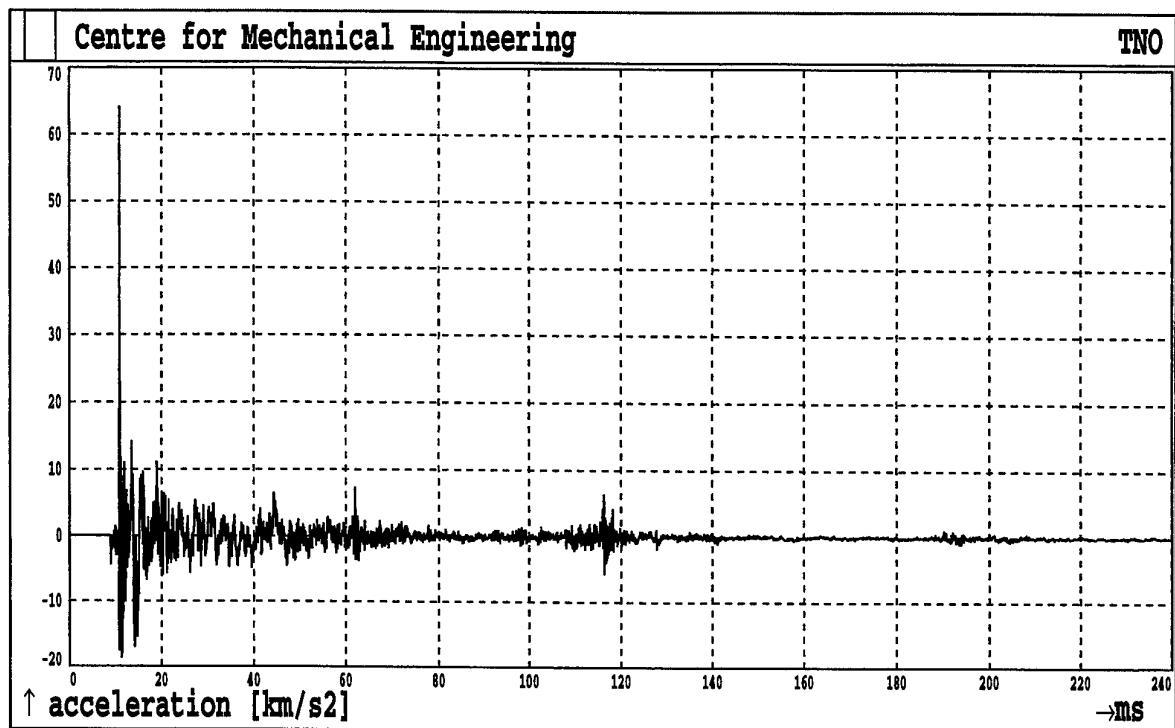
Fig.321. Shot 6   Sensor A9

Fig.322. Shot 6   Sensor A10

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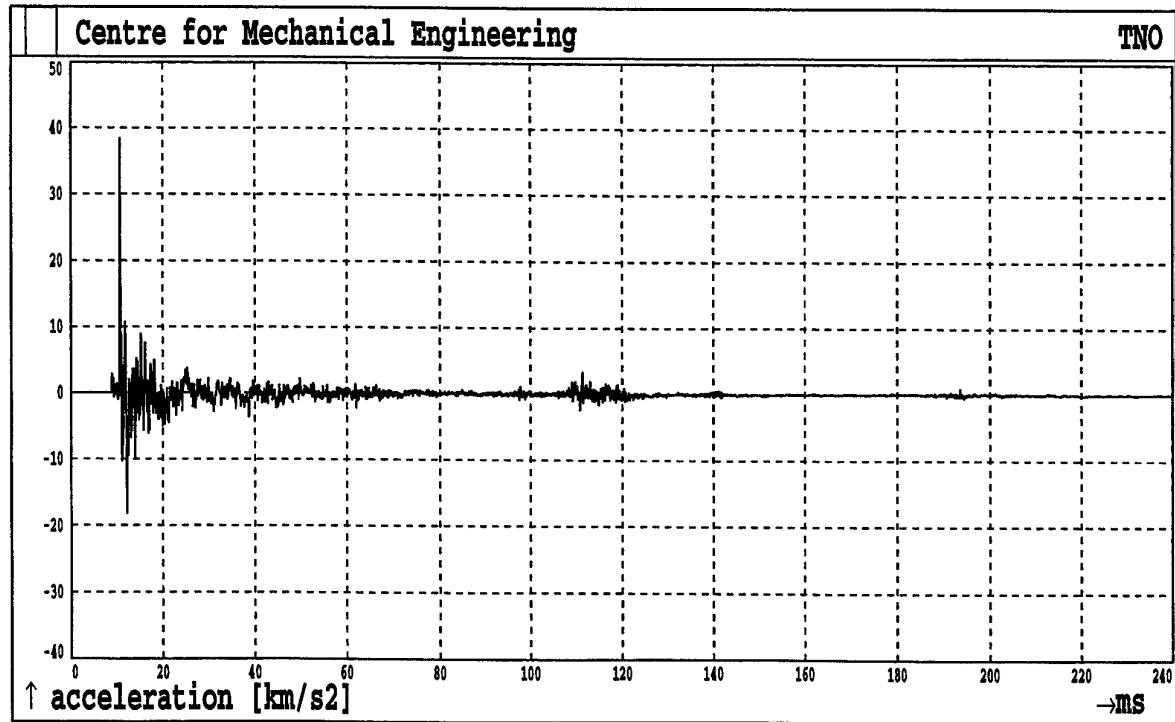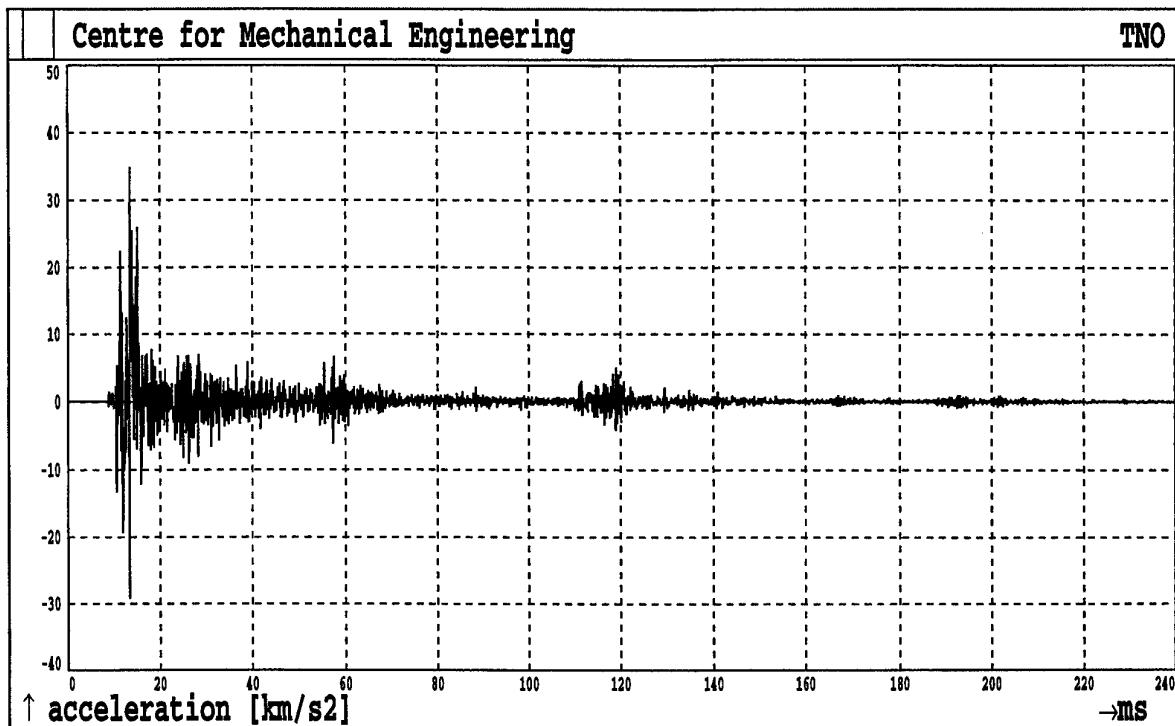
Fig.323. Shot 6   Sensor A11

Fig.324. Shot 6   Sensor A12

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↑ acceleration [km/s2]
→ms

Fig.325. Shot 6   Sensor A13

Centre for Mechanical Engineering   **TNO**

↑ acceleration [km/s2]
→ms

Fig.326. Shot 6   Sensor A14

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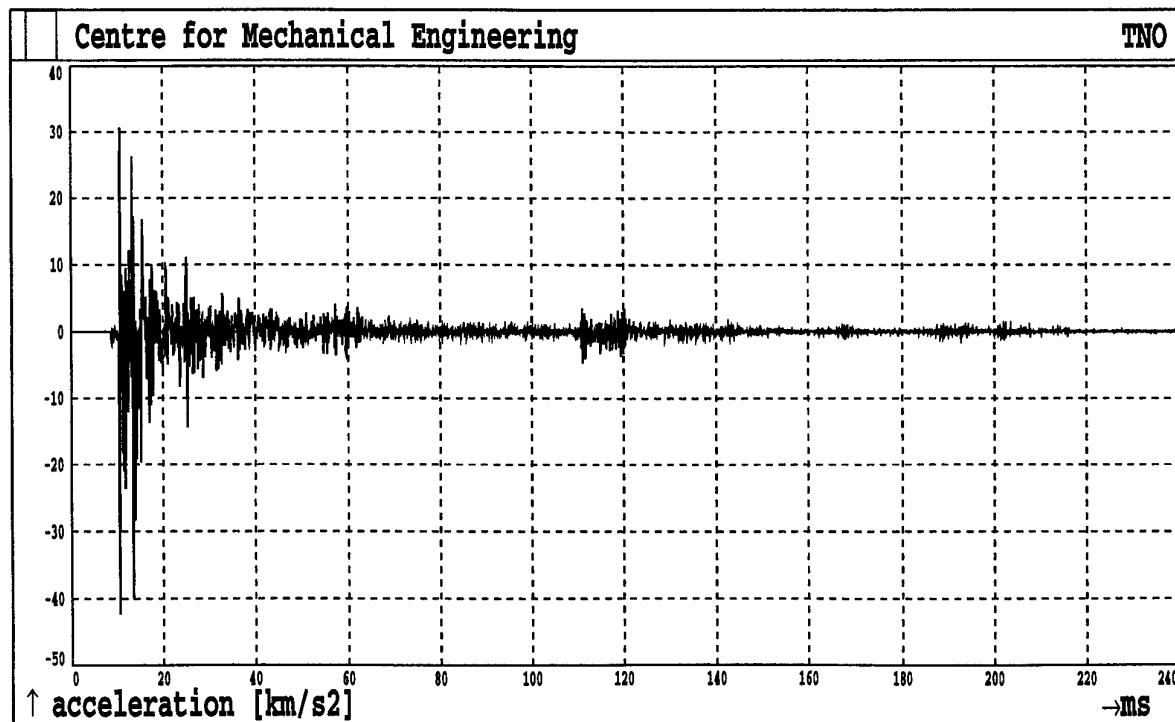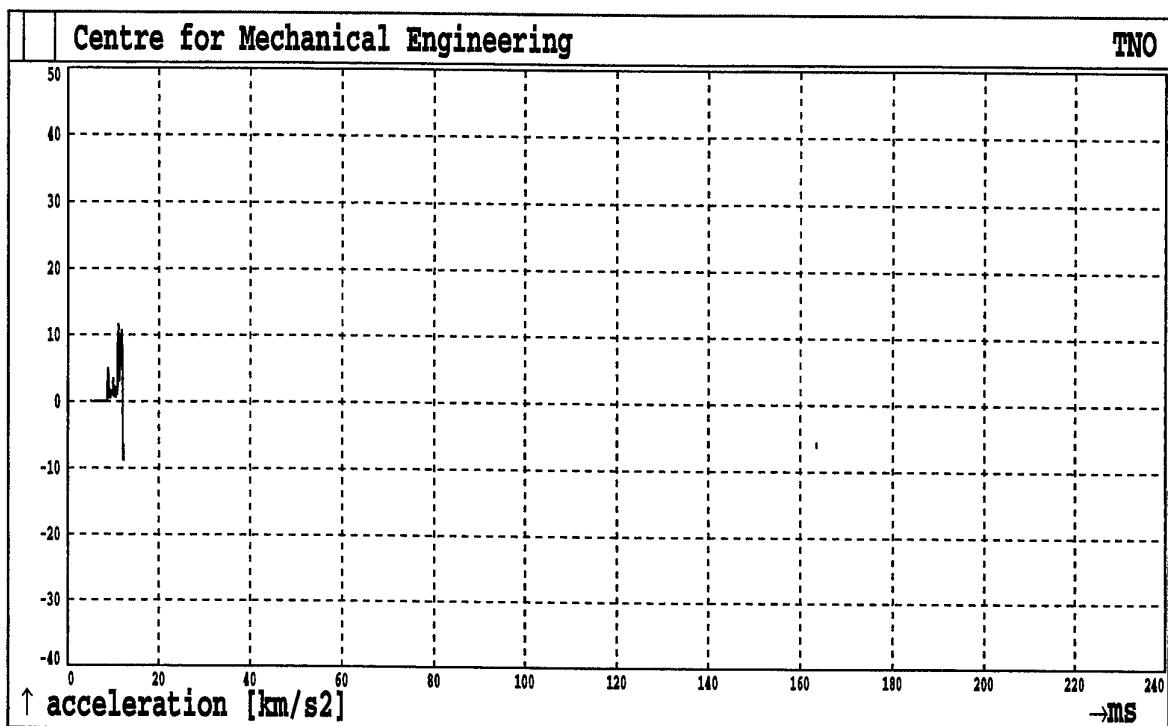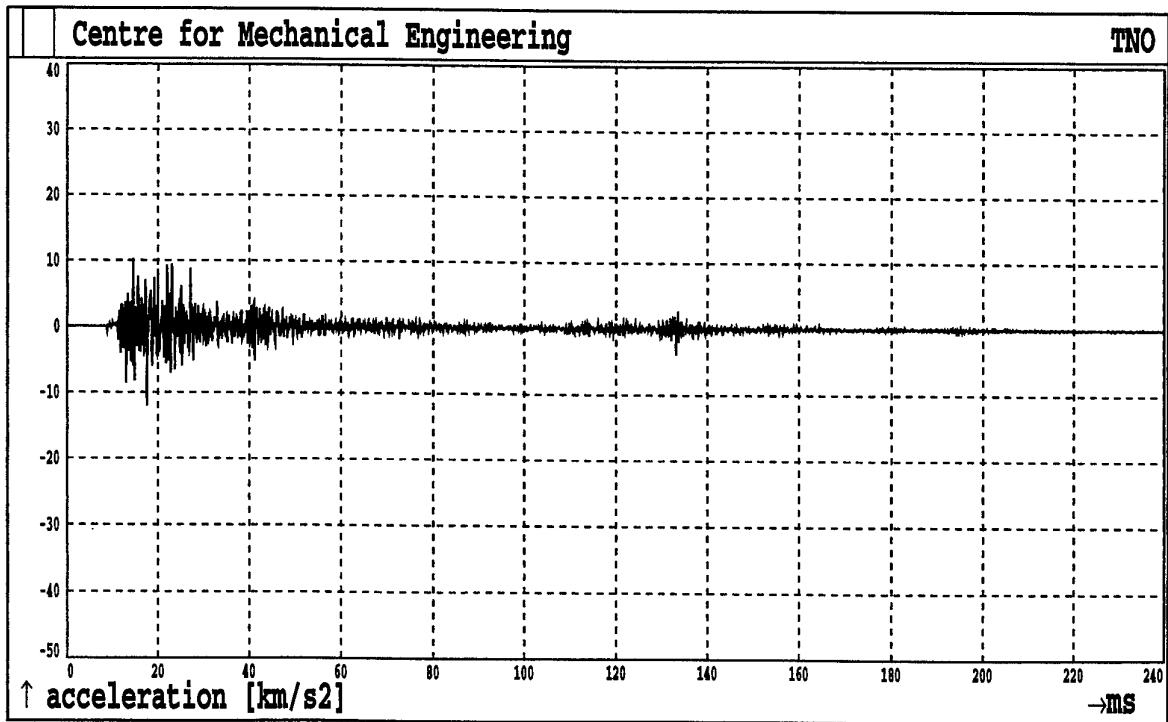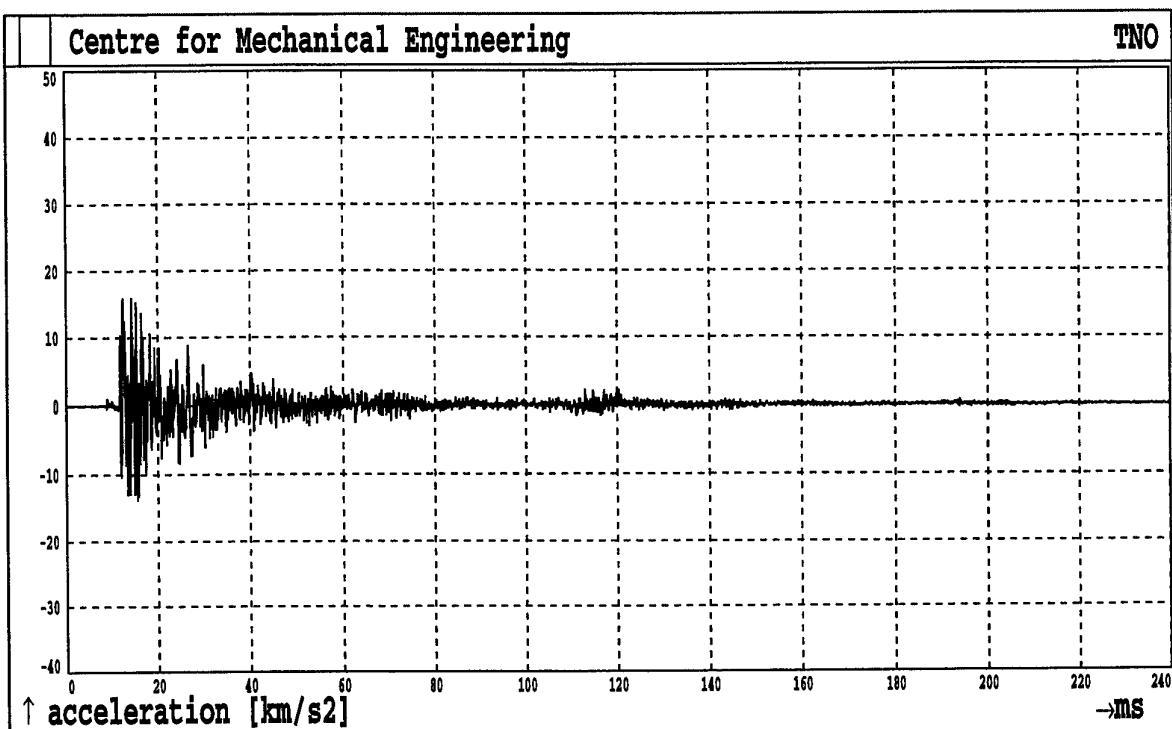
Fig.327. Shot 6   Sensor A15

Fig.328. Shot 6   Sensor A16

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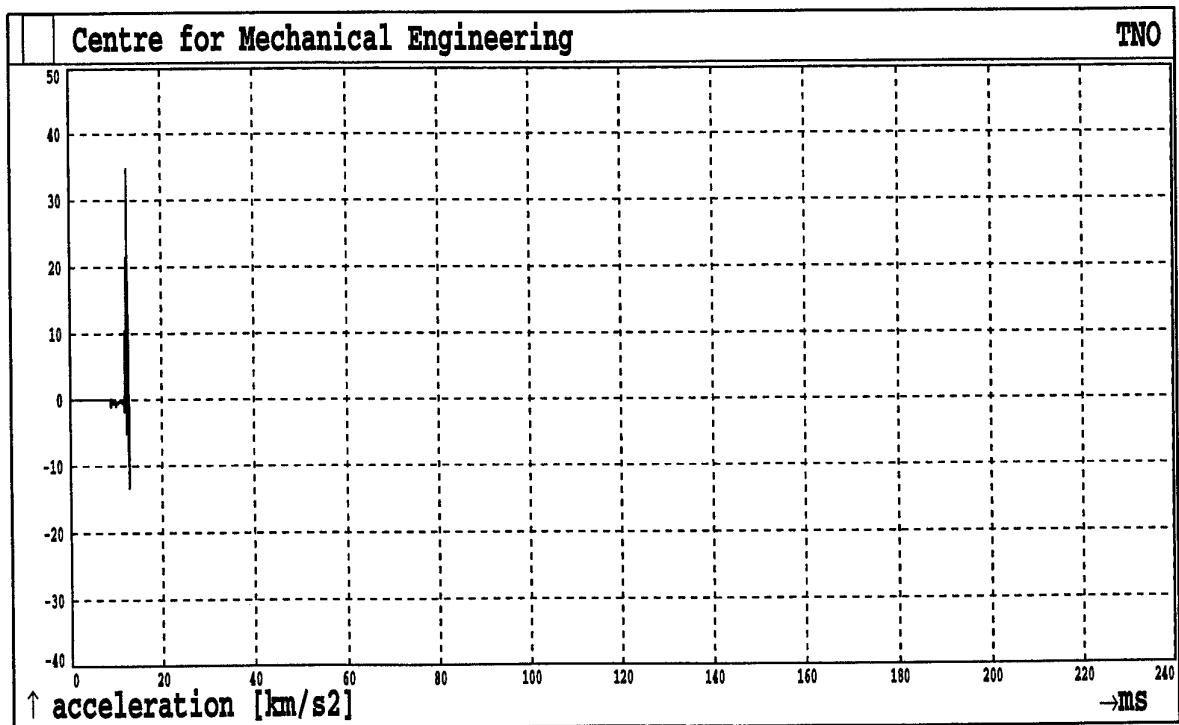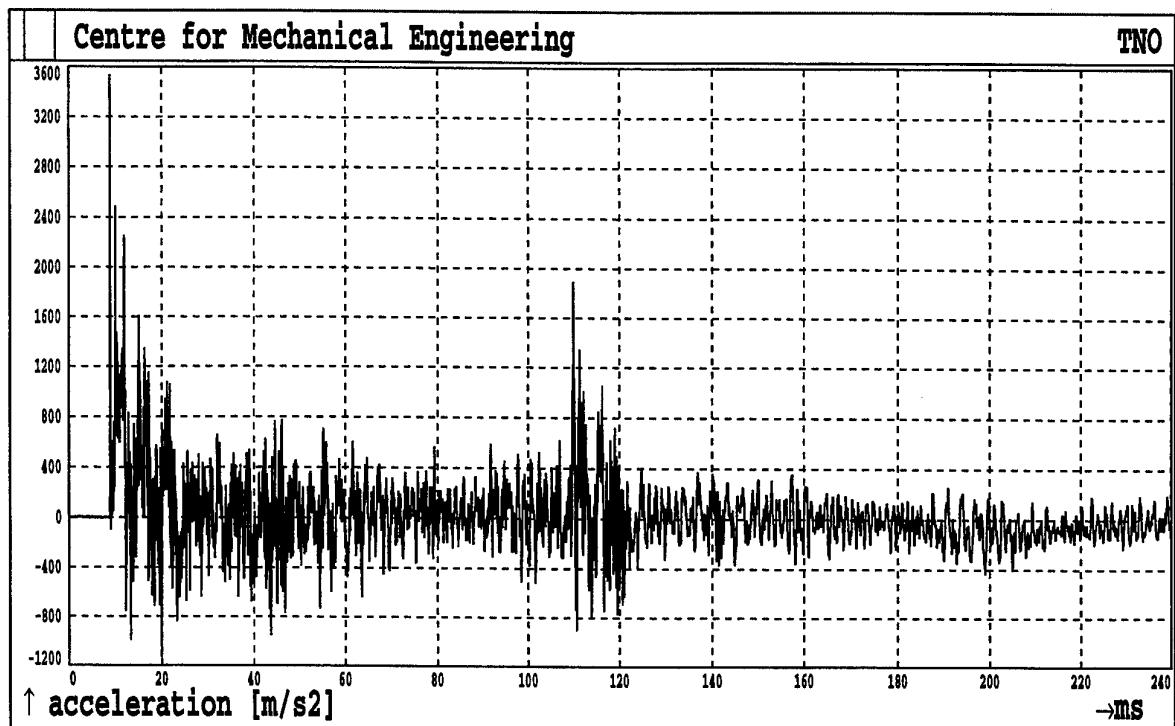
Fig.329. Shot 6 Sensor A17

Fig.330. Shot 6 Sensor A22

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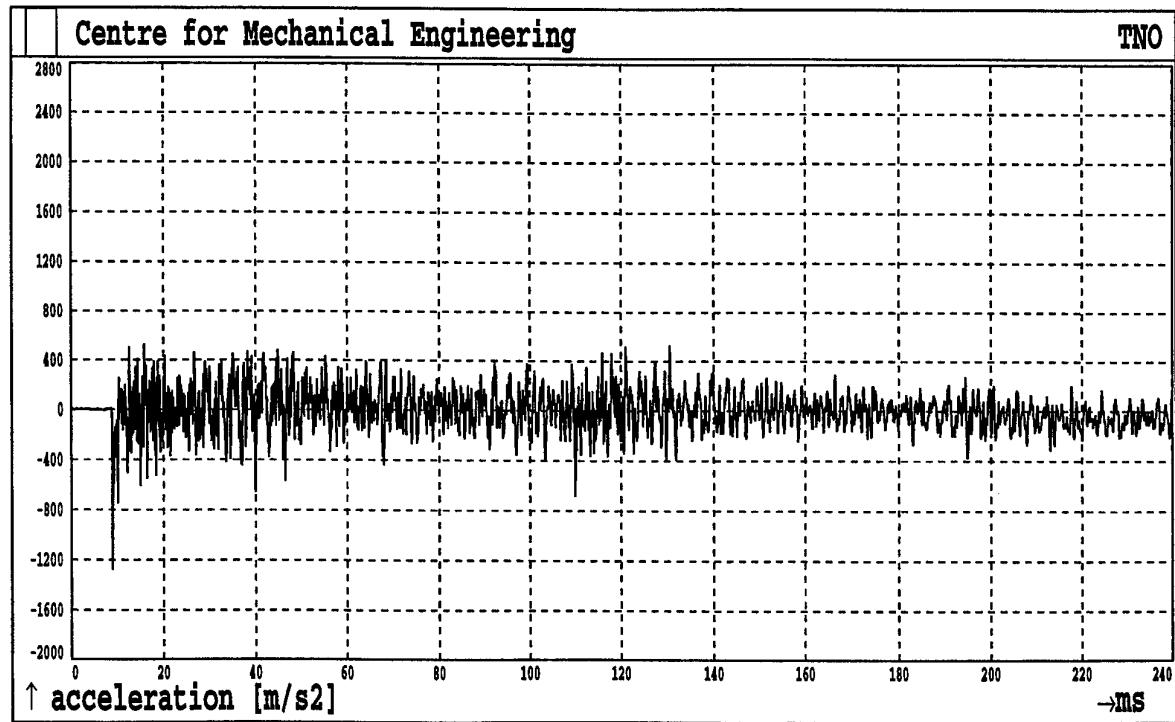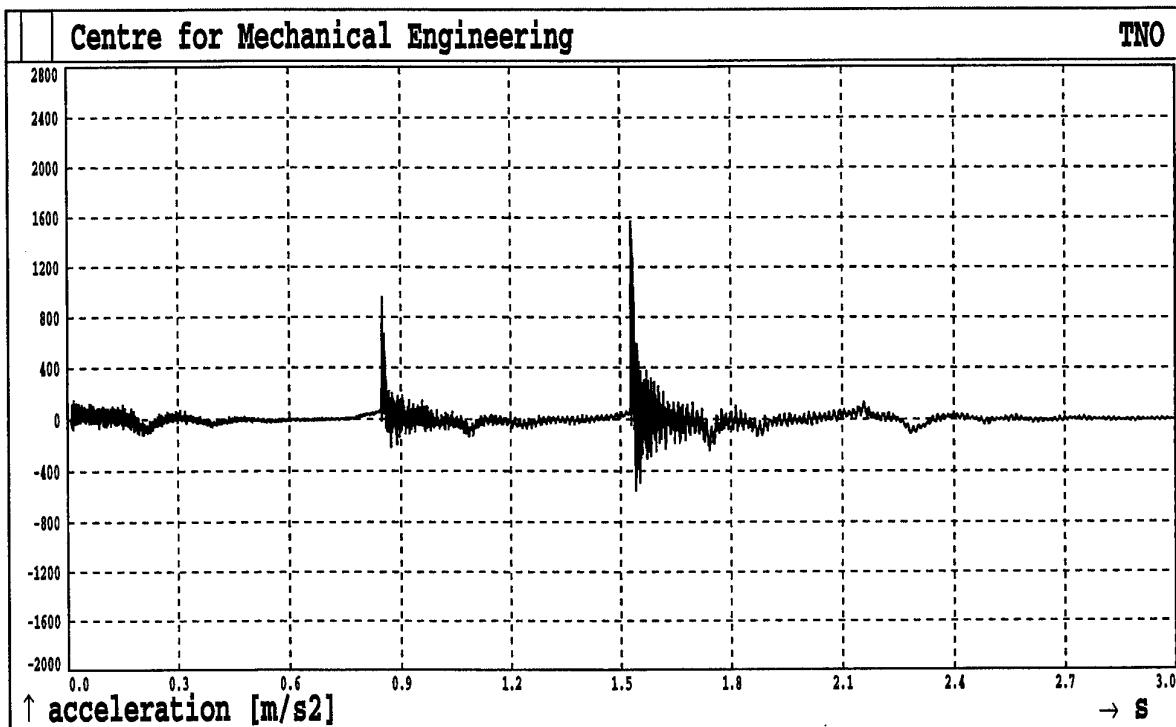
Fig.331. Shot 6   Sensor A25

Fig.332. Shot 6   Sensor A26

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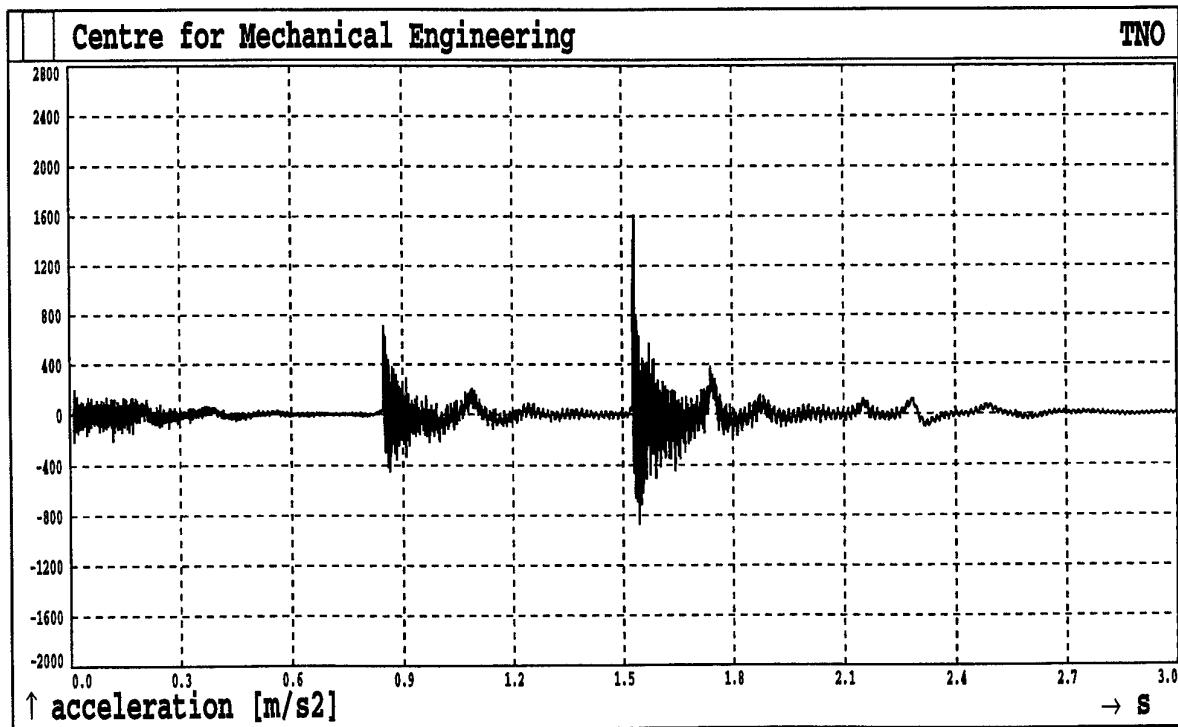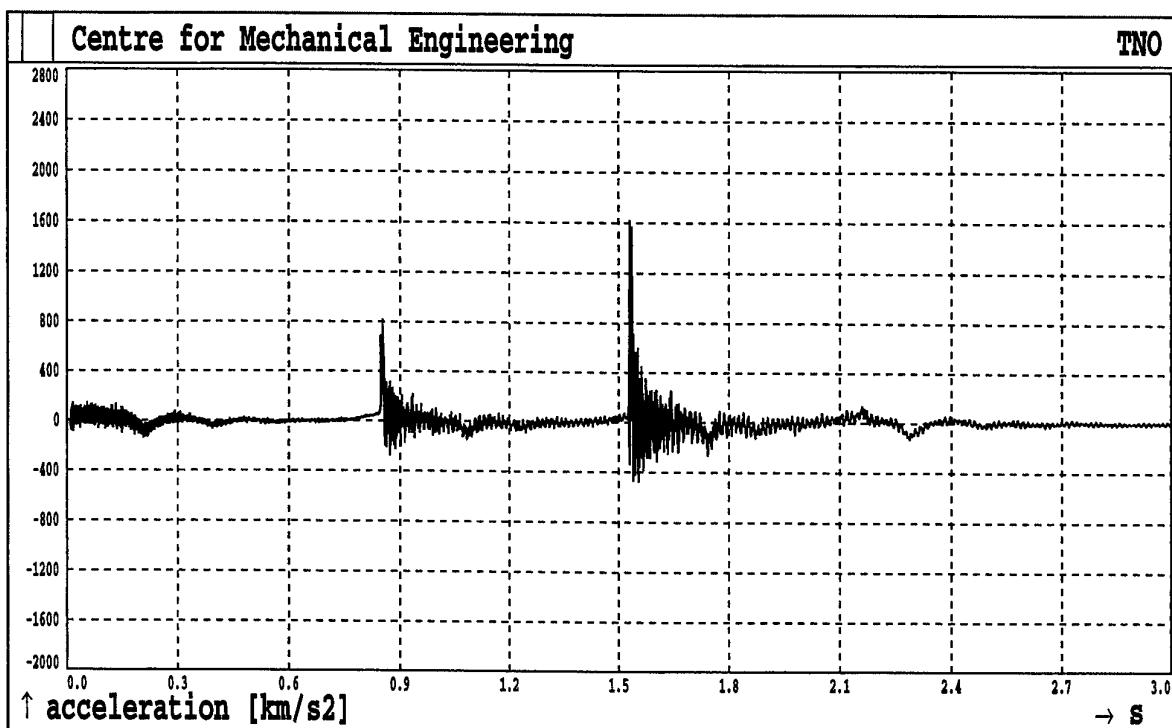
Fig.333. Shot 6   Sensor A27

Fig.334. Shot 6   Sensor A28

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↑ velocity [m/s]   →ms

Fig.335. Shot 6 Sensor A2

Centre for Mechanical Engineering   TNO

↑ velocity [m/s]   →ms

Fig.336. Shot 6 Sensor A5

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↑ velocity [m/s] →ms

Fig.337. Shot 6 Sensor A6

Centre for Mechanical Engineering **TNO**

↑ velocity [m/s] →ms
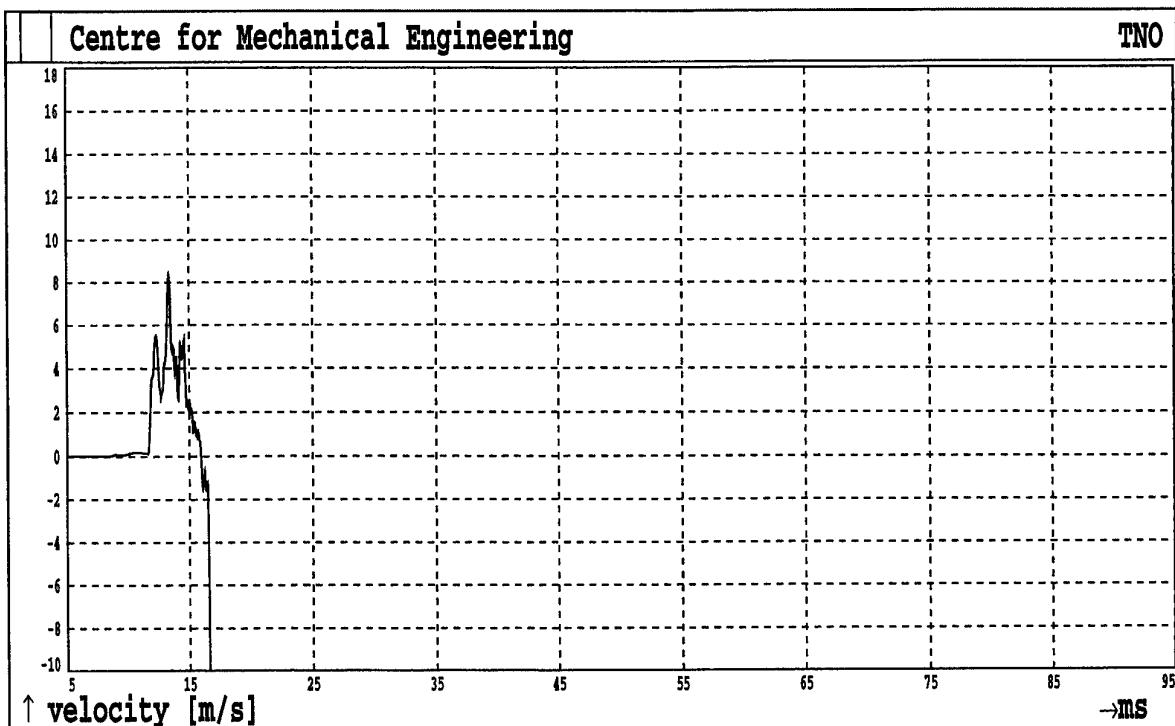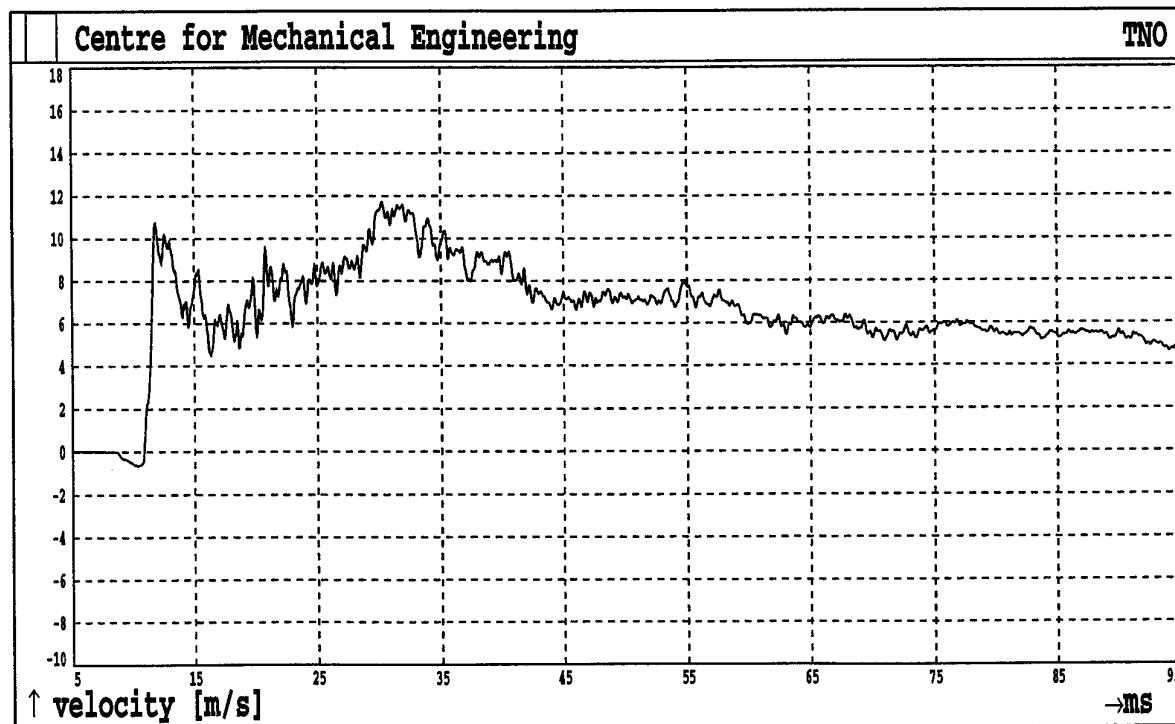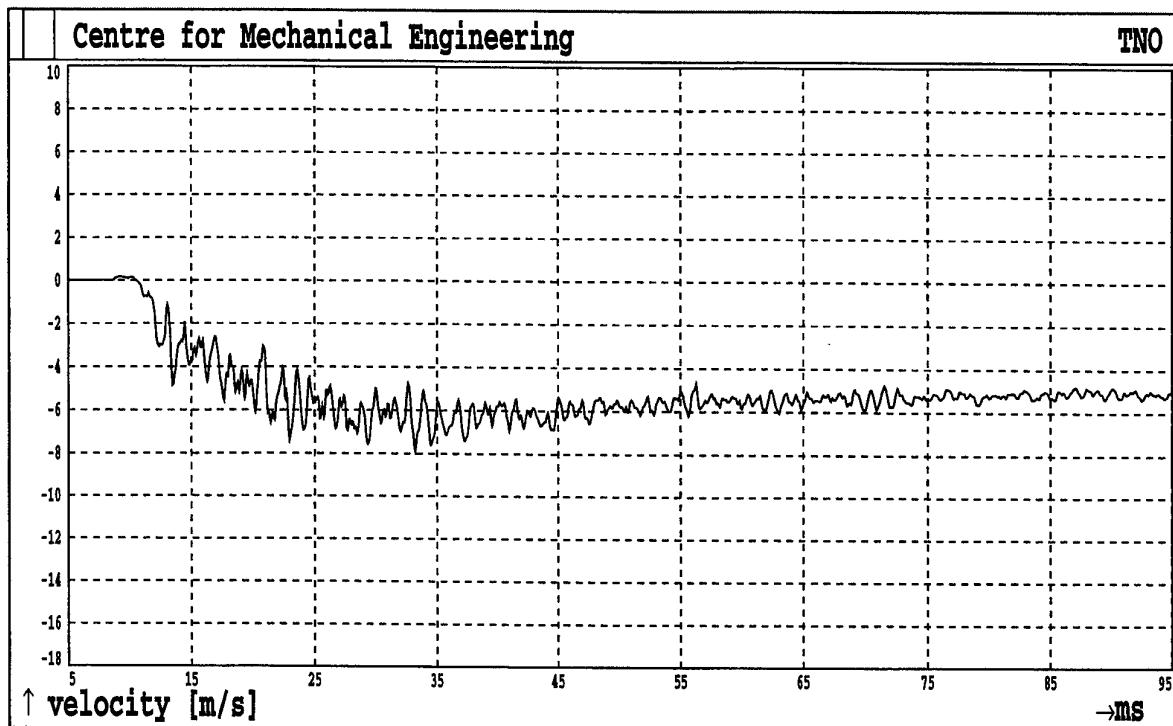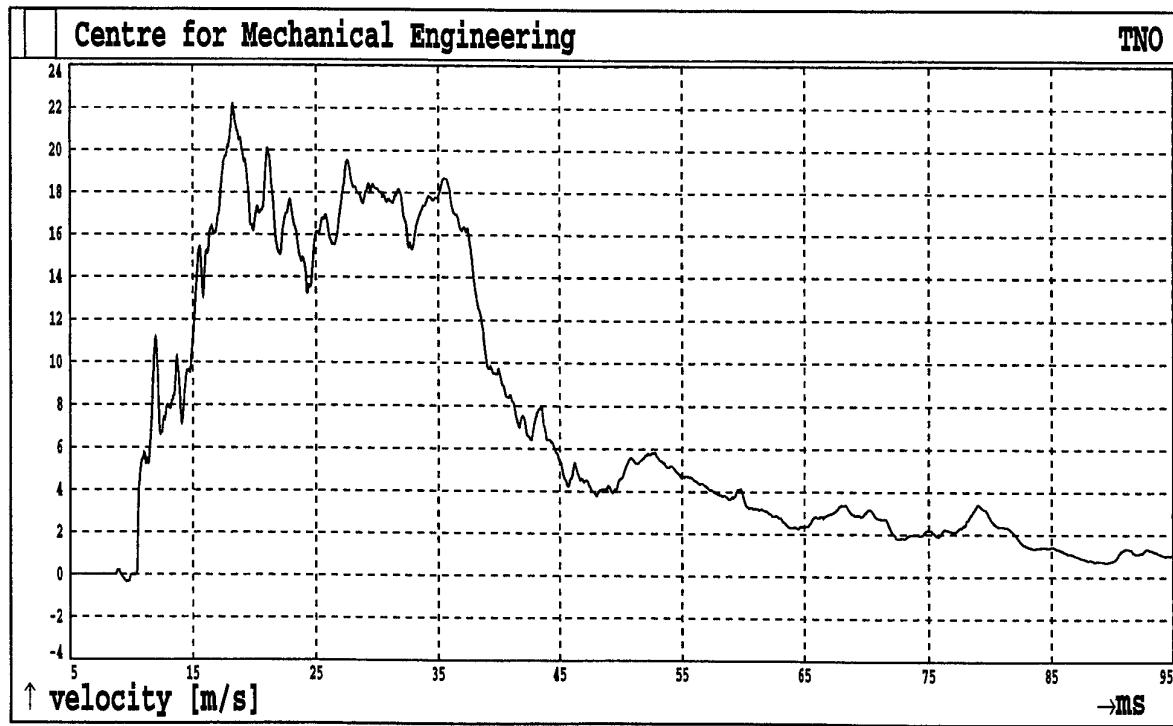
Fig.338. Shot 6 Sensor A8
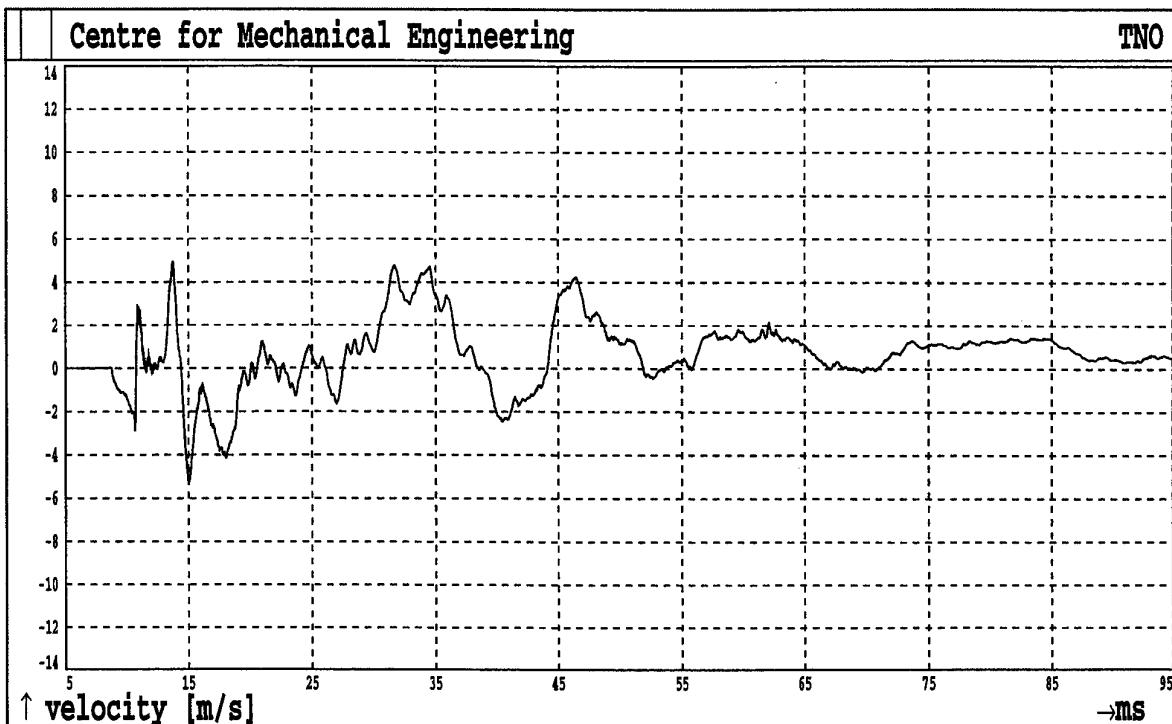
Fig.339. Shot 6　Sensor A9

Fig.340. Shot 6　Sensor A10

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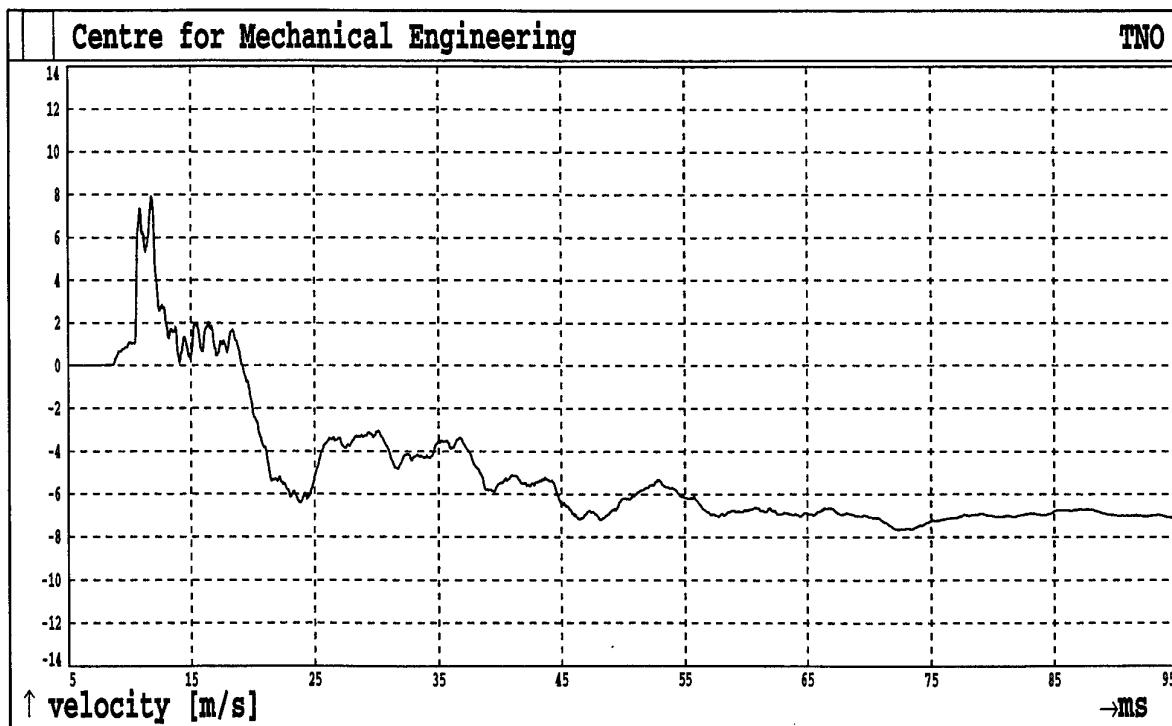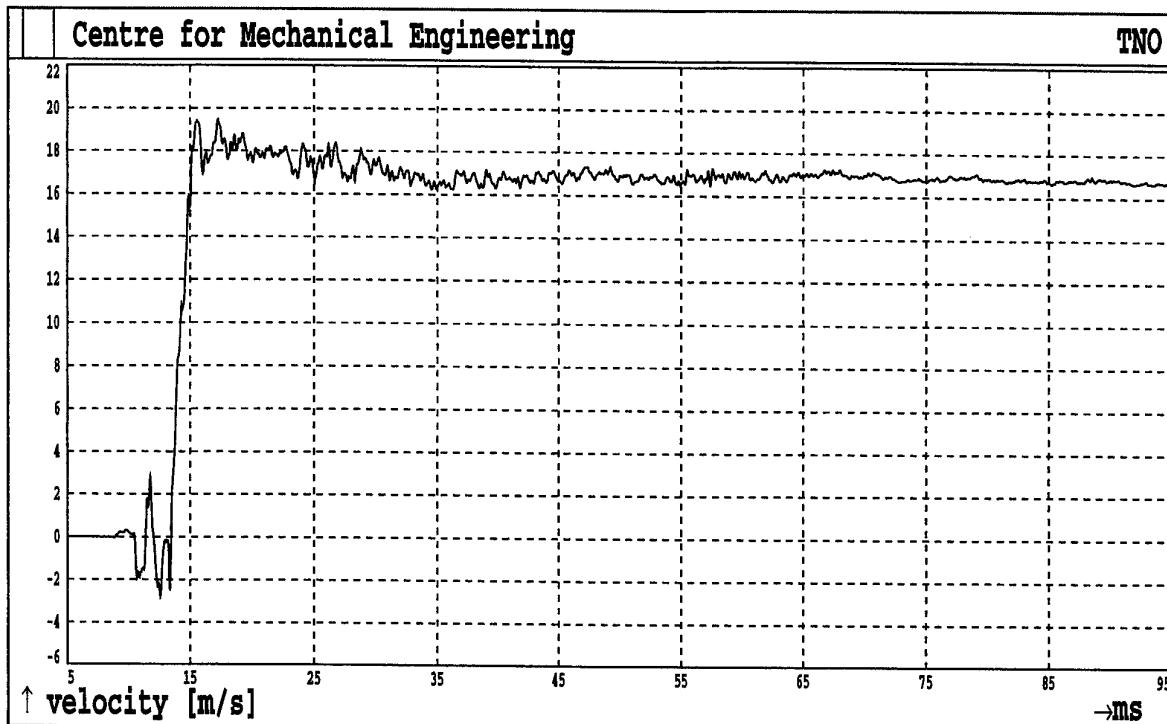
Fig.341. Shot 6   Sensor A11

Fig.342. Shot 6   Sensor A12

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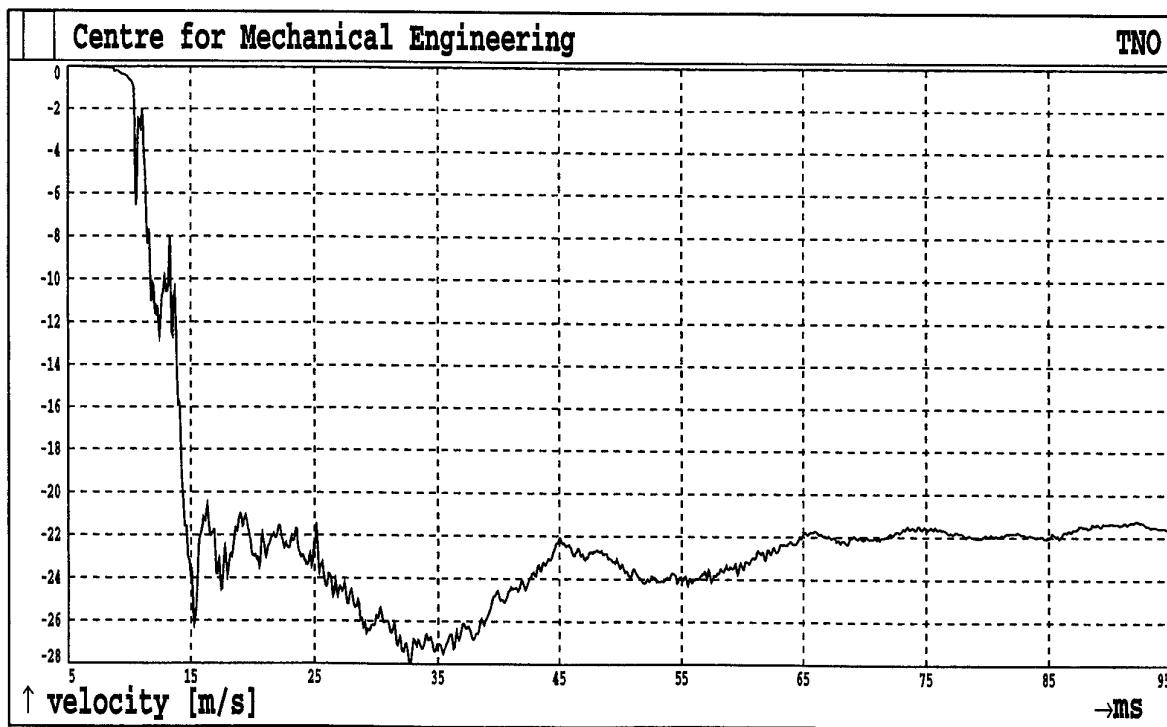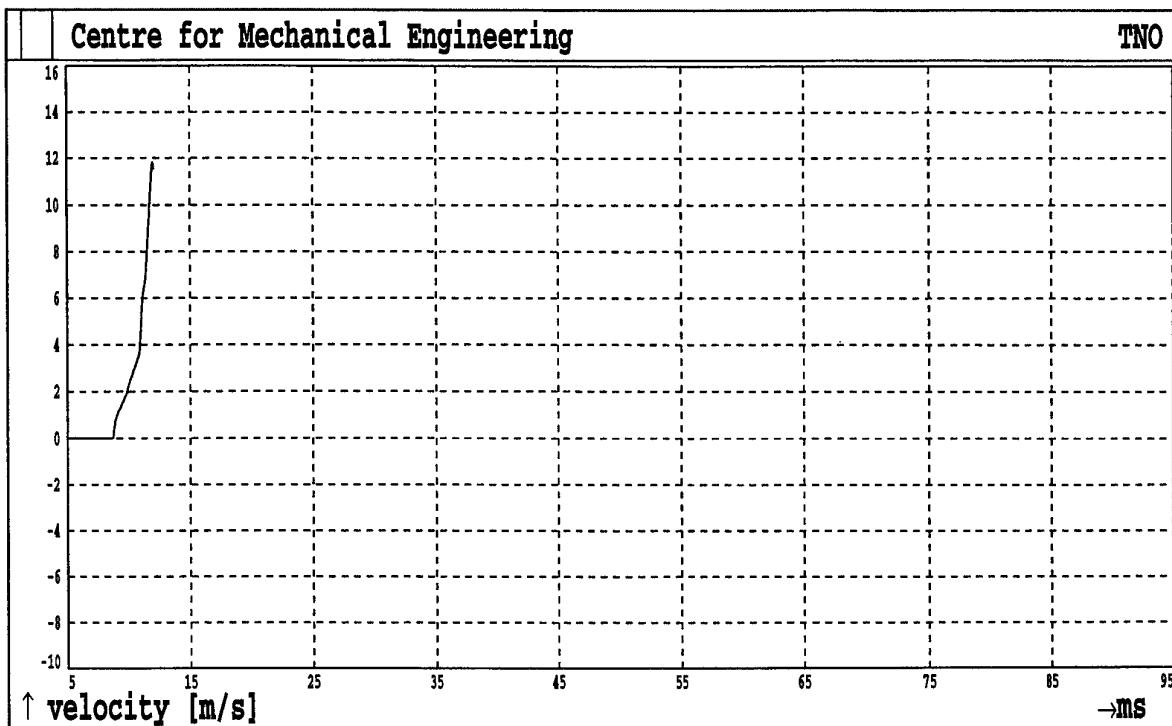
Fig.343. Shot 6   Sensor A13

Fig.344. Shot 6   Sensor A14

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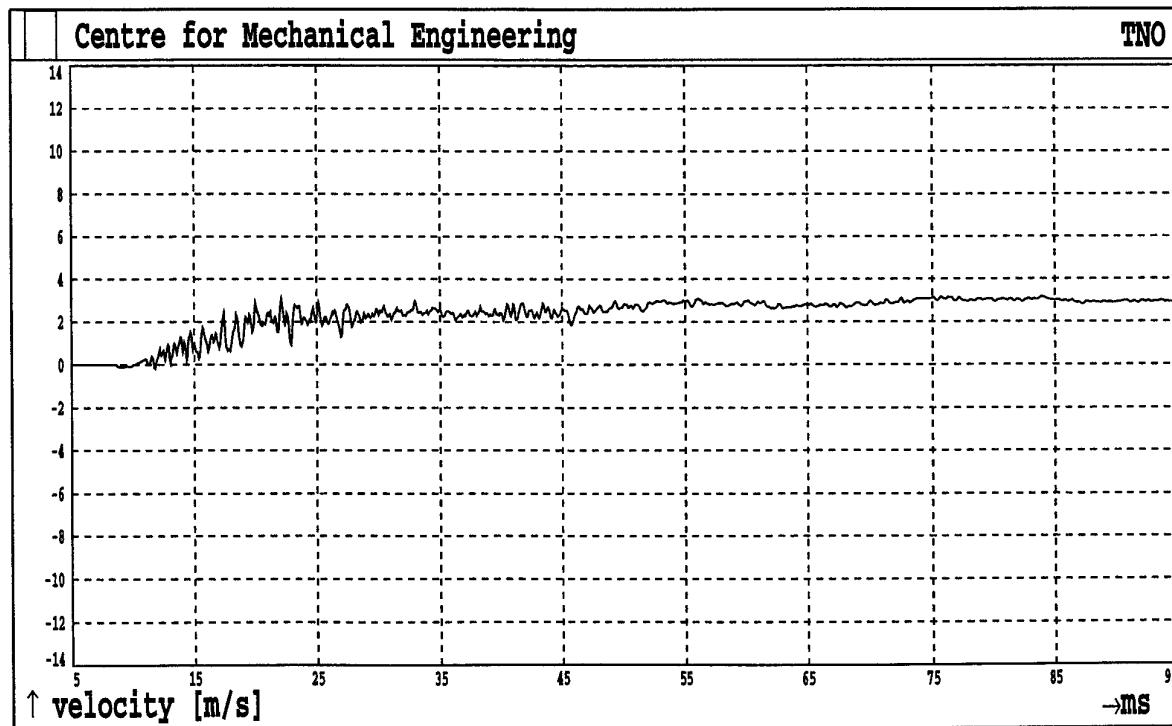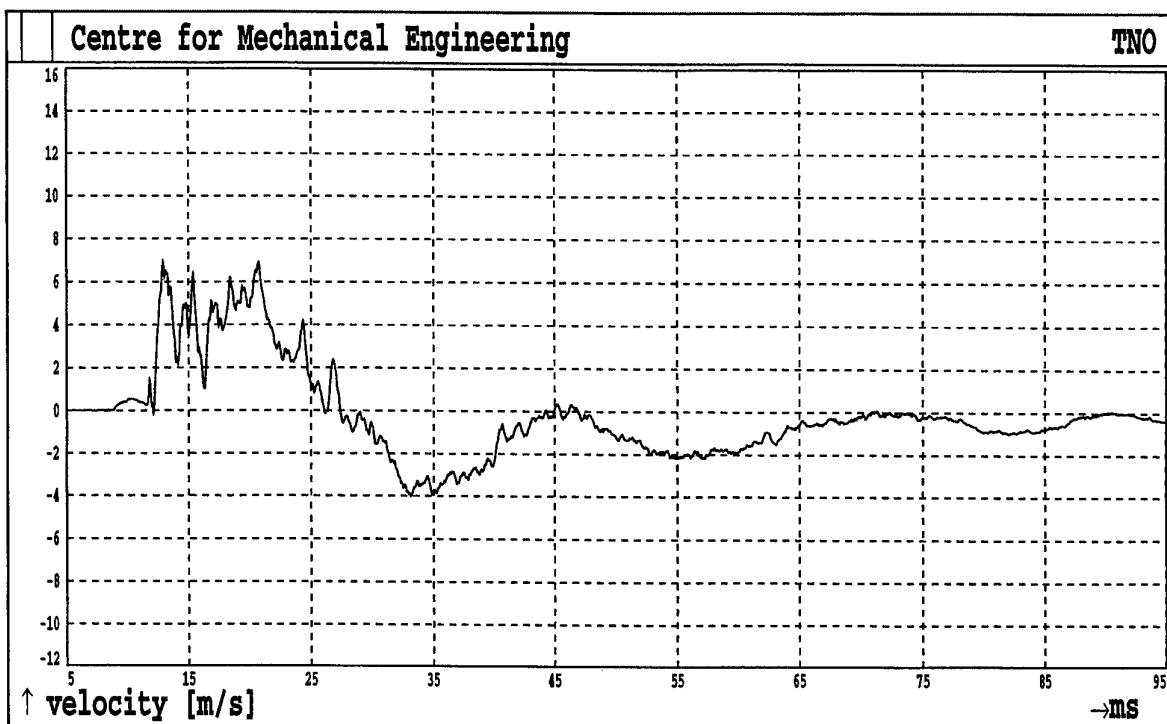
Fig.345. Shot 6   Sensor A15

Fig.346. Shot 6   Sensor A16

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↑ velocity [m/s]   →ms

Fig.347. Shot 6   Sensor A17

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↑ velocity [m/s]   →ms

Fig.348. Shot 6   Sensor A22

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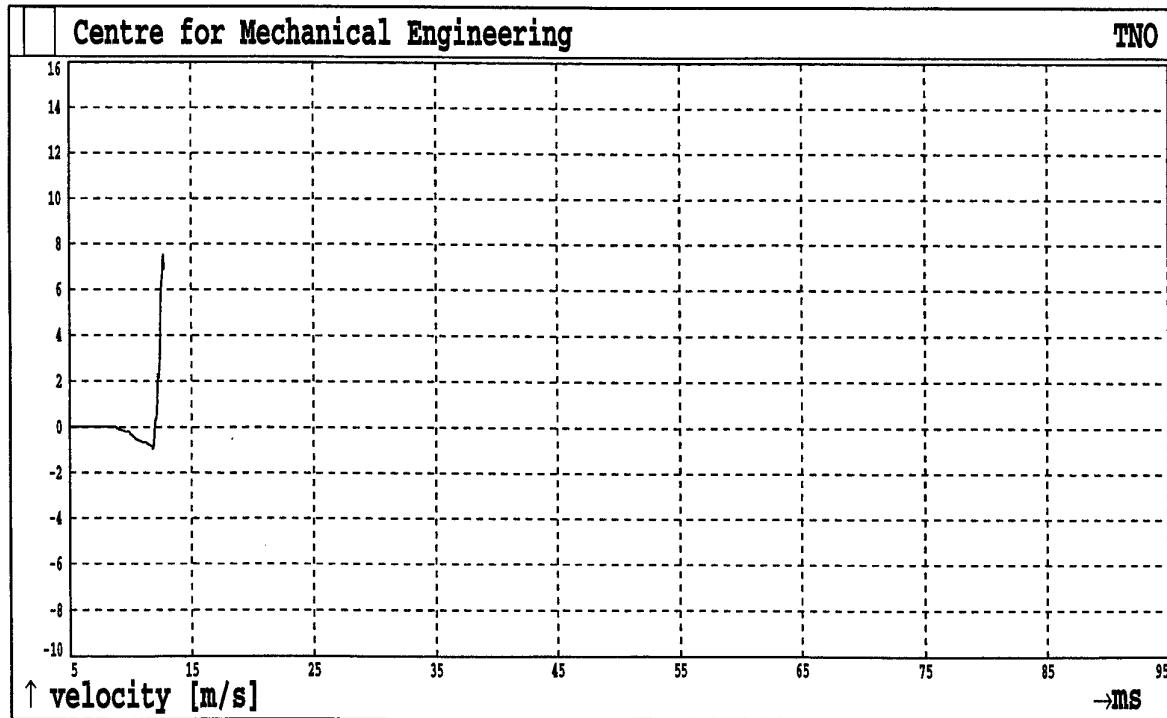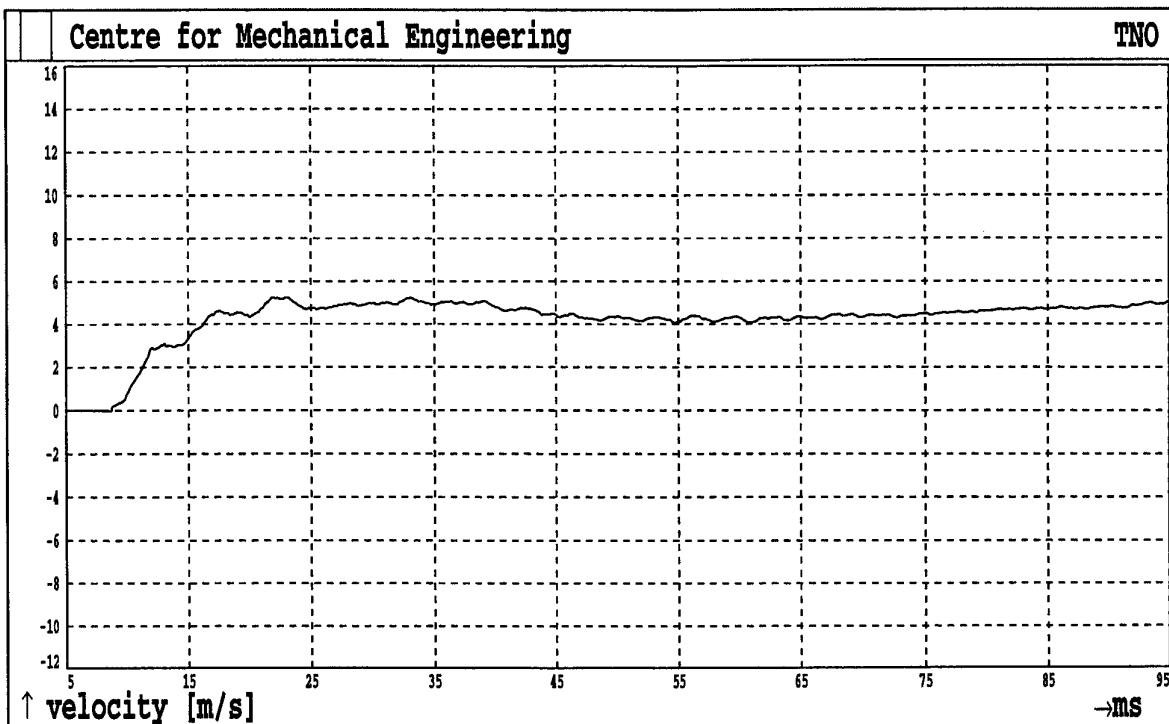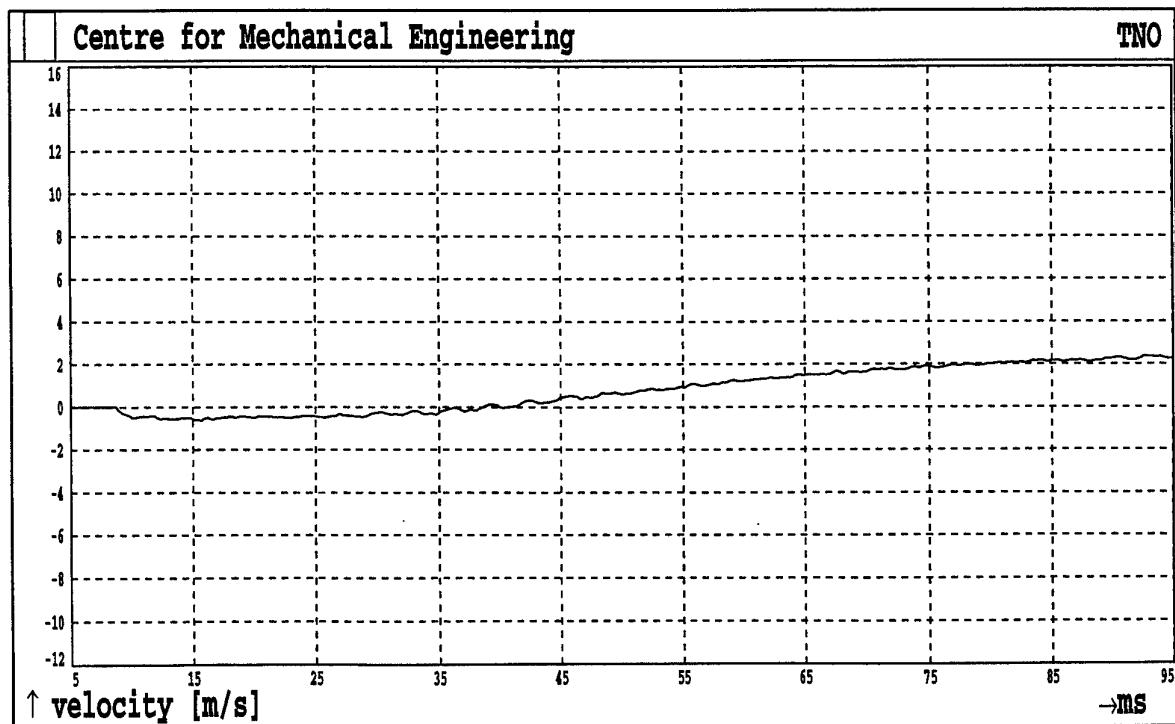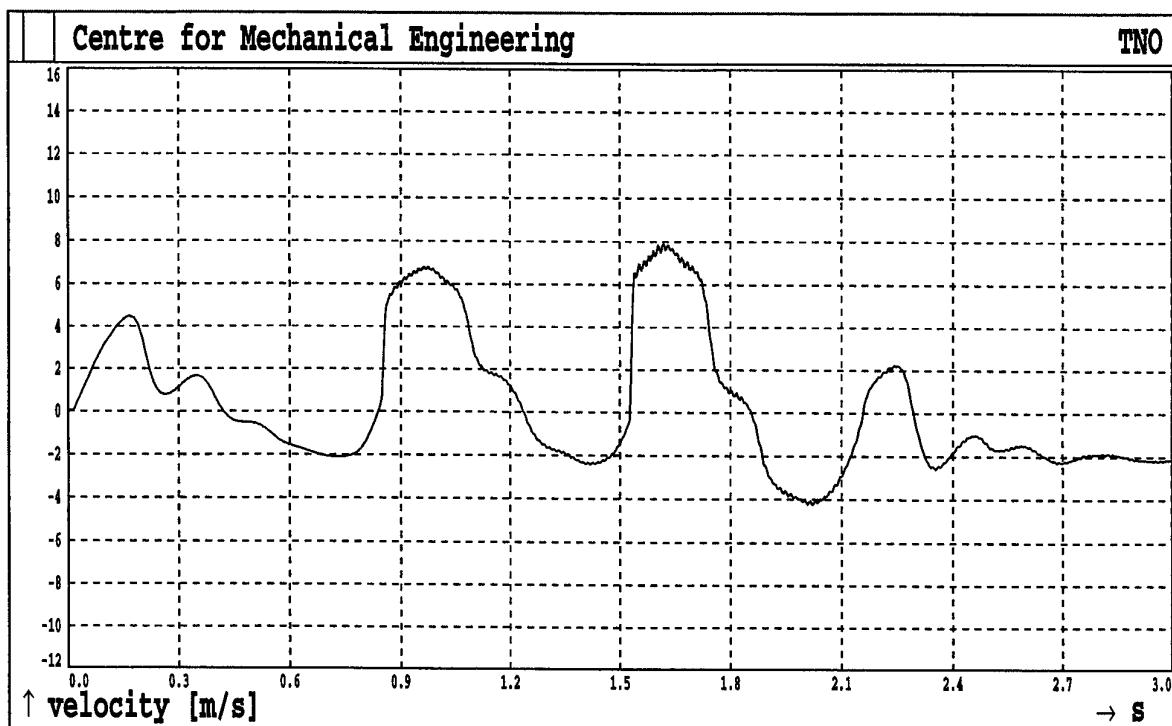
Fig.349. Shot 6   Sensor A25

Fig.350. Shot 6   Sensor A26

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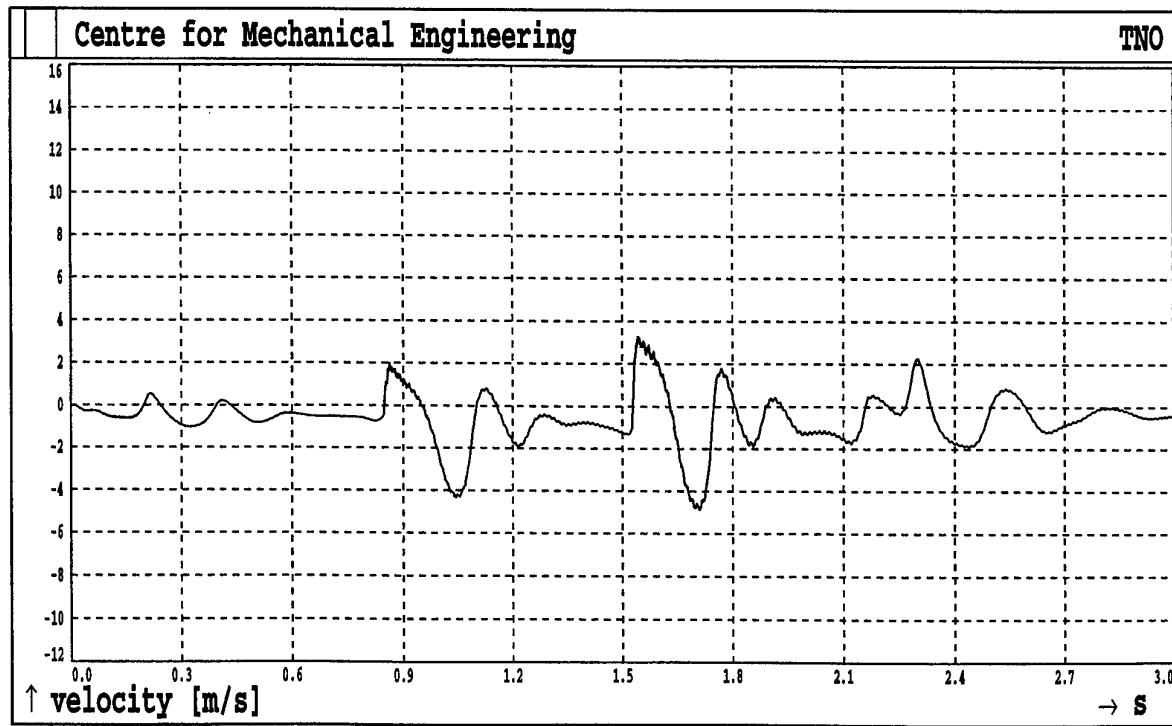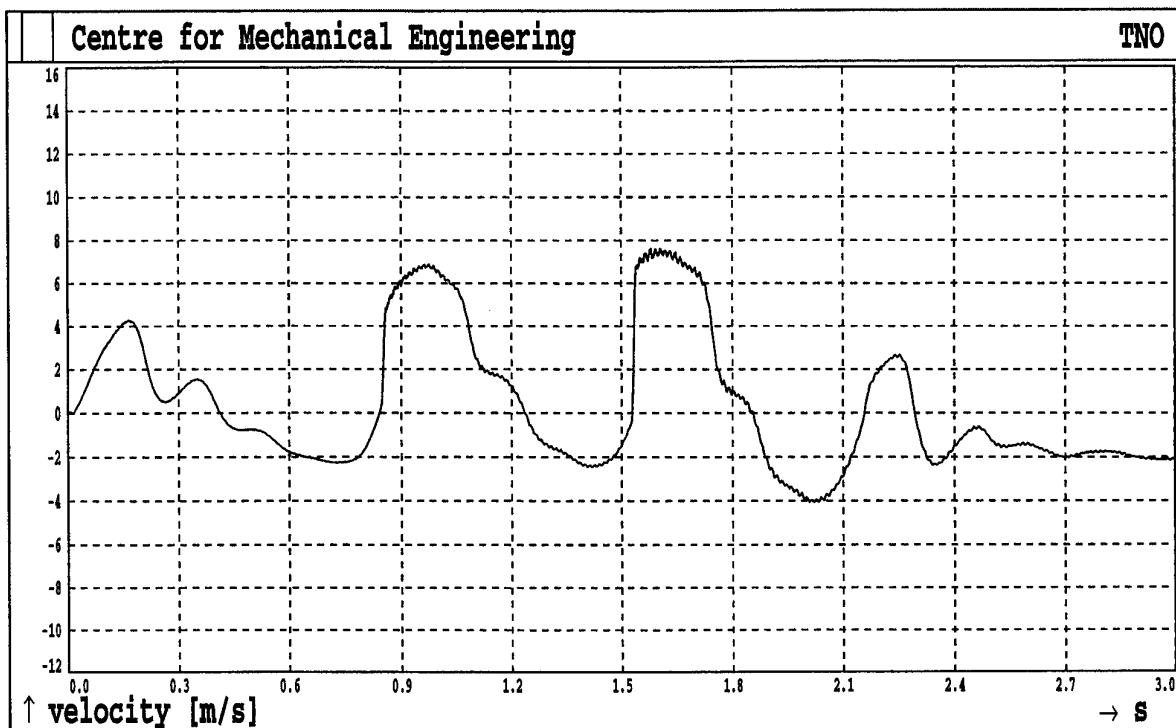
Fig.351. Shot 6   Sensor A27

Fig.352. Shot 6   Sensor A28

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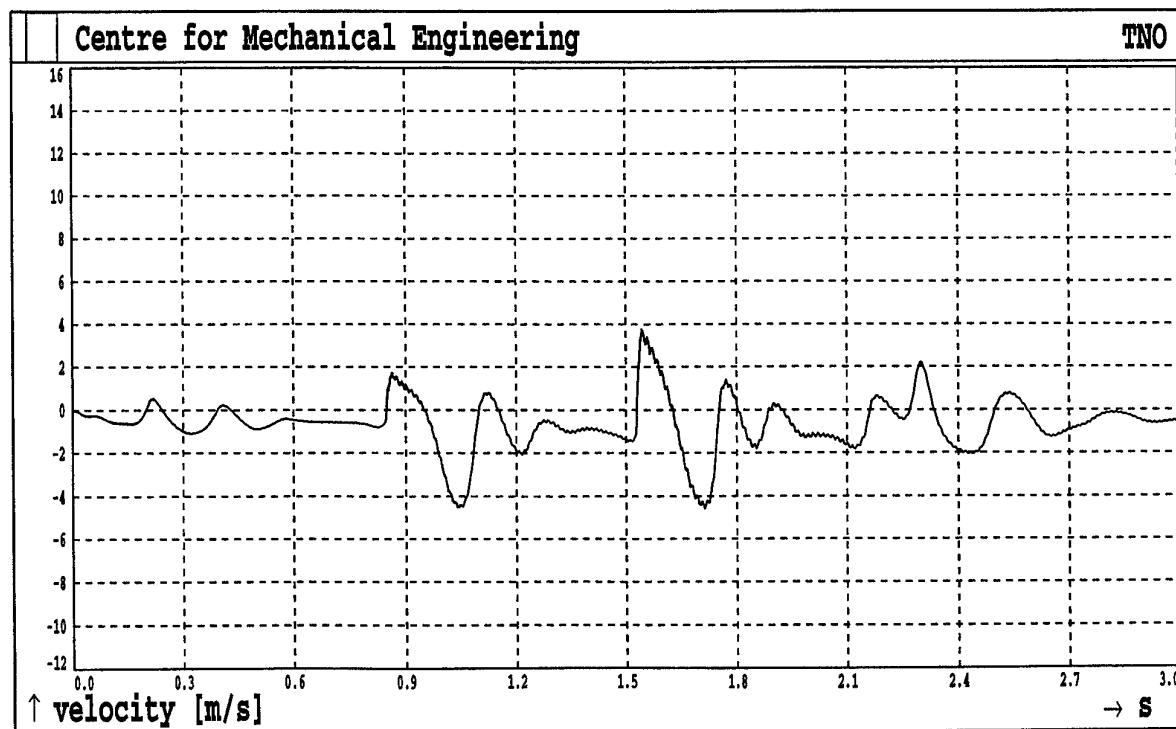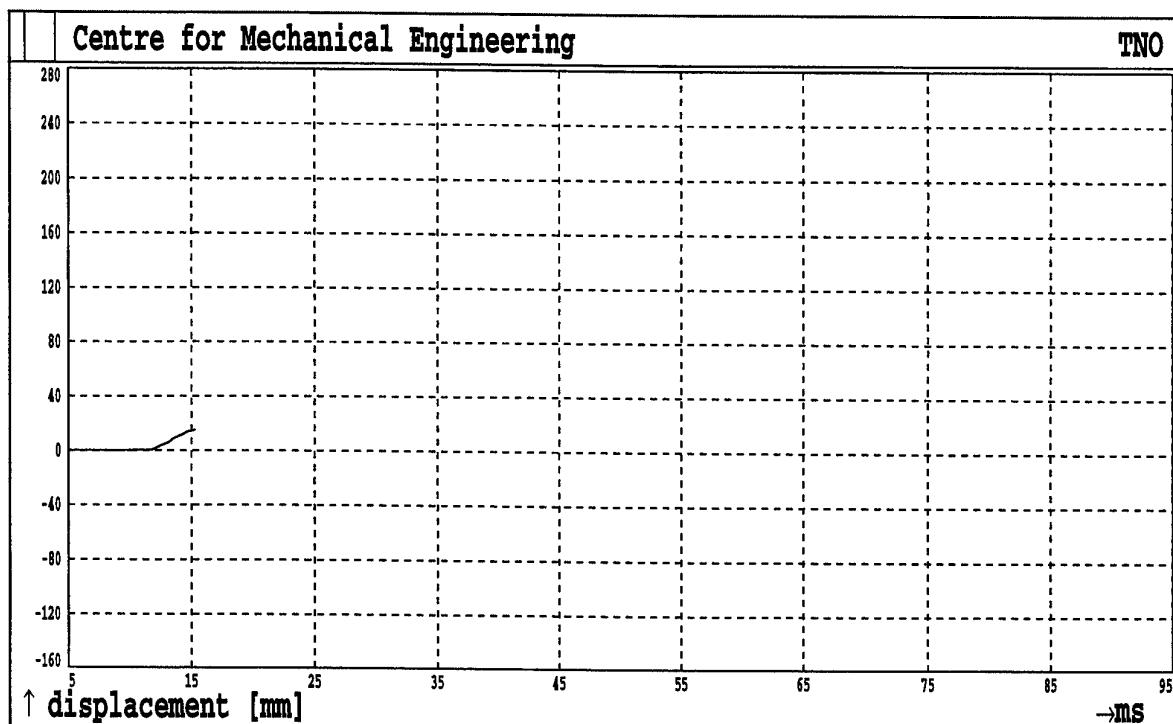
Fig.353. Shot 6   Sensor A2

Fig.354. Shot 6   Sensor A5

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↑ displacement [mm]

→ms

Fig.355. Shot 6   Sensor A6

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↑ displacement [mm]

→ms
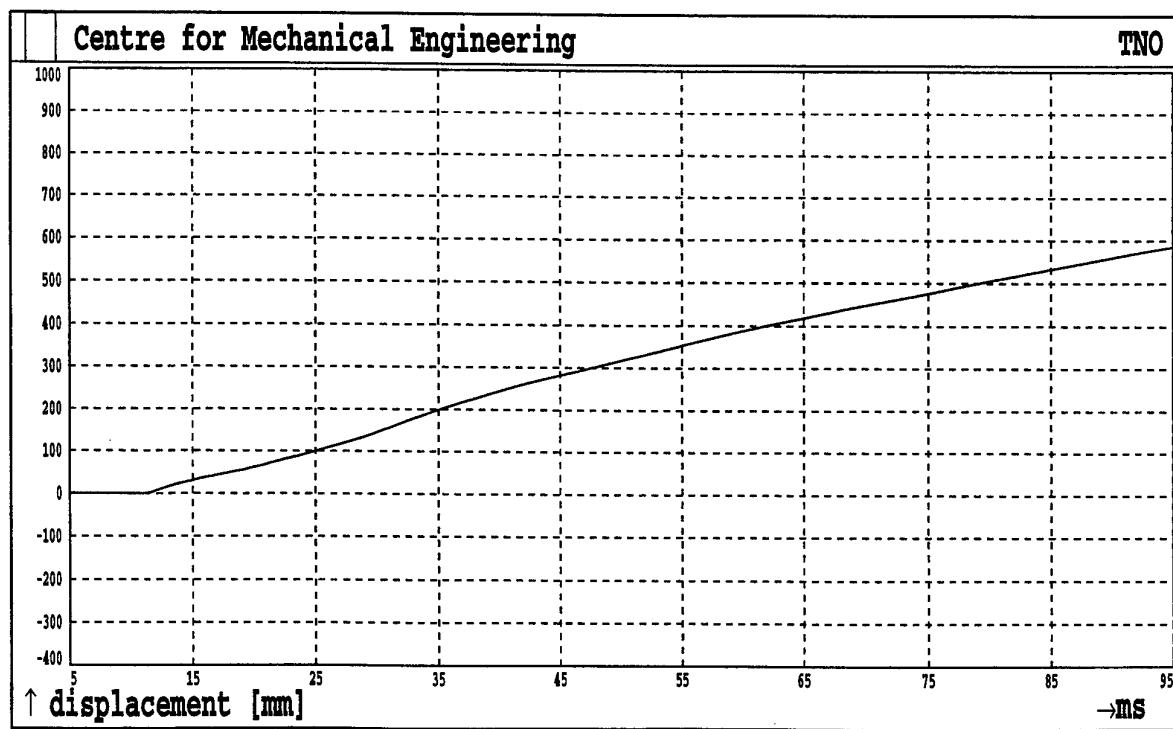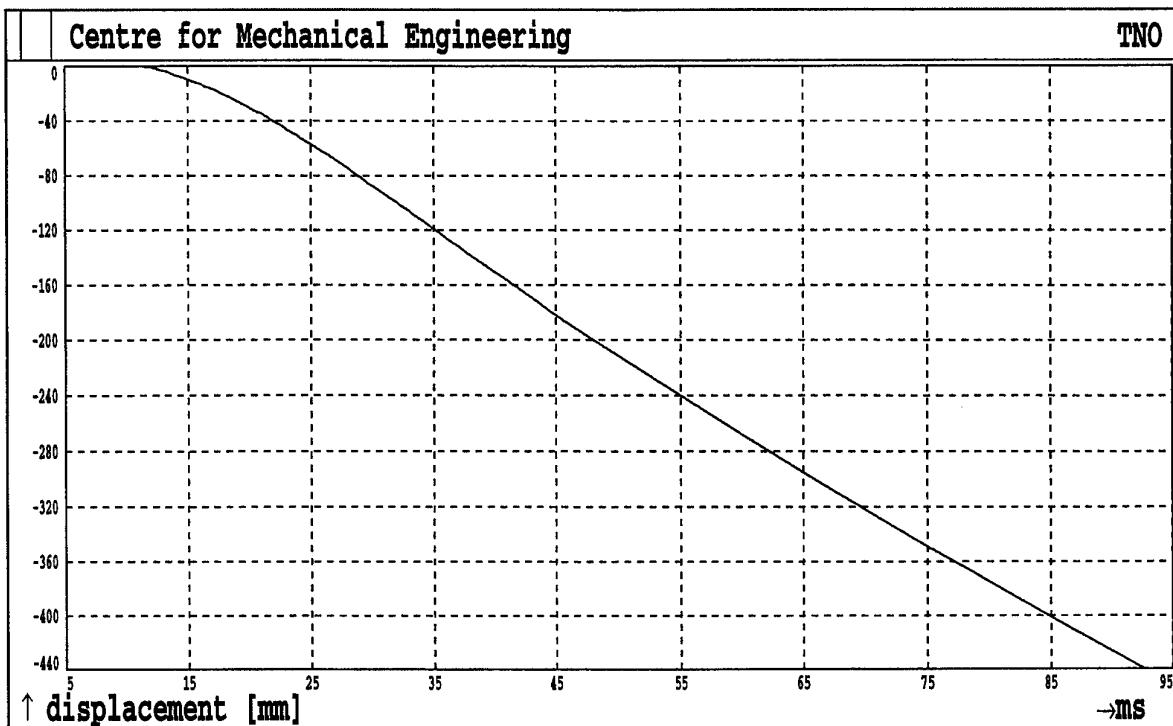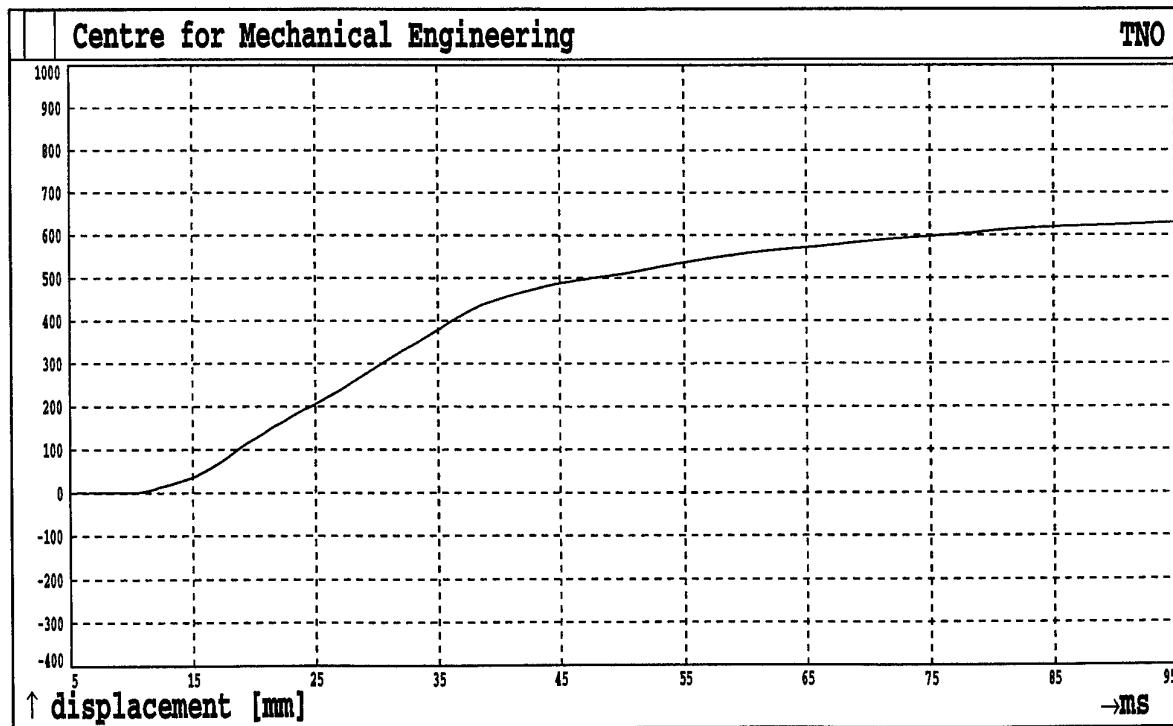
Fig.356. Shot 6   Sensor A8
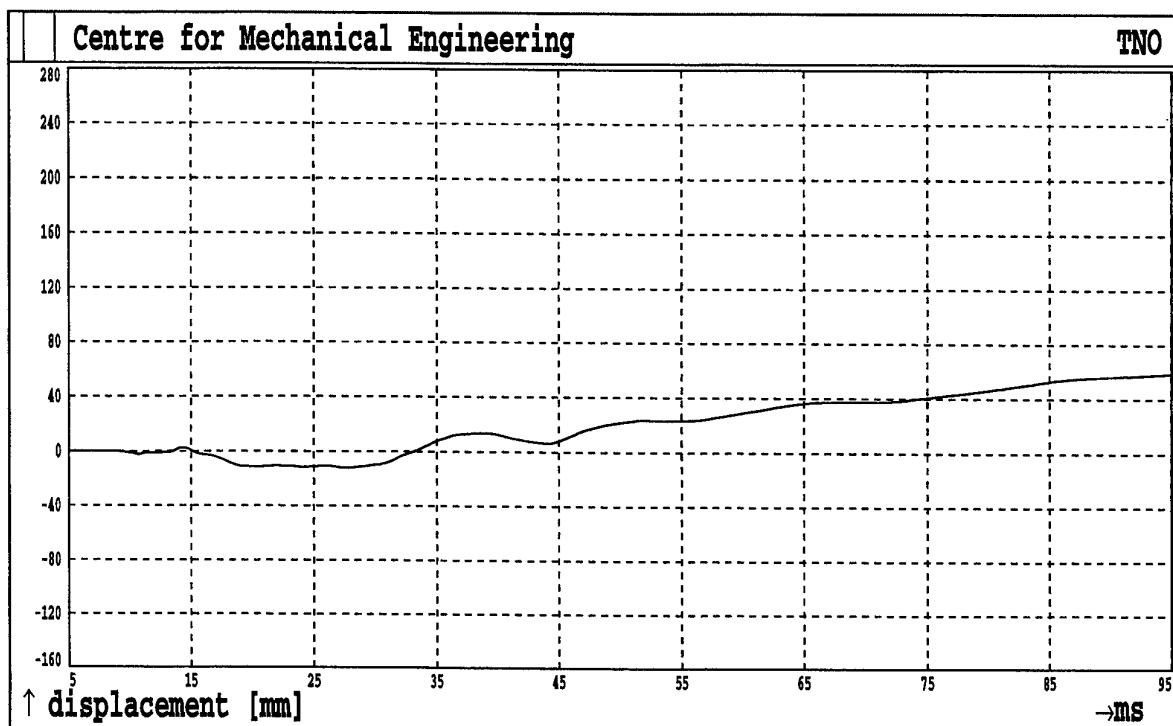
**Fig.357. Shot 6　Sensor A9**

Fig.358. Shot 6　Sensor A10

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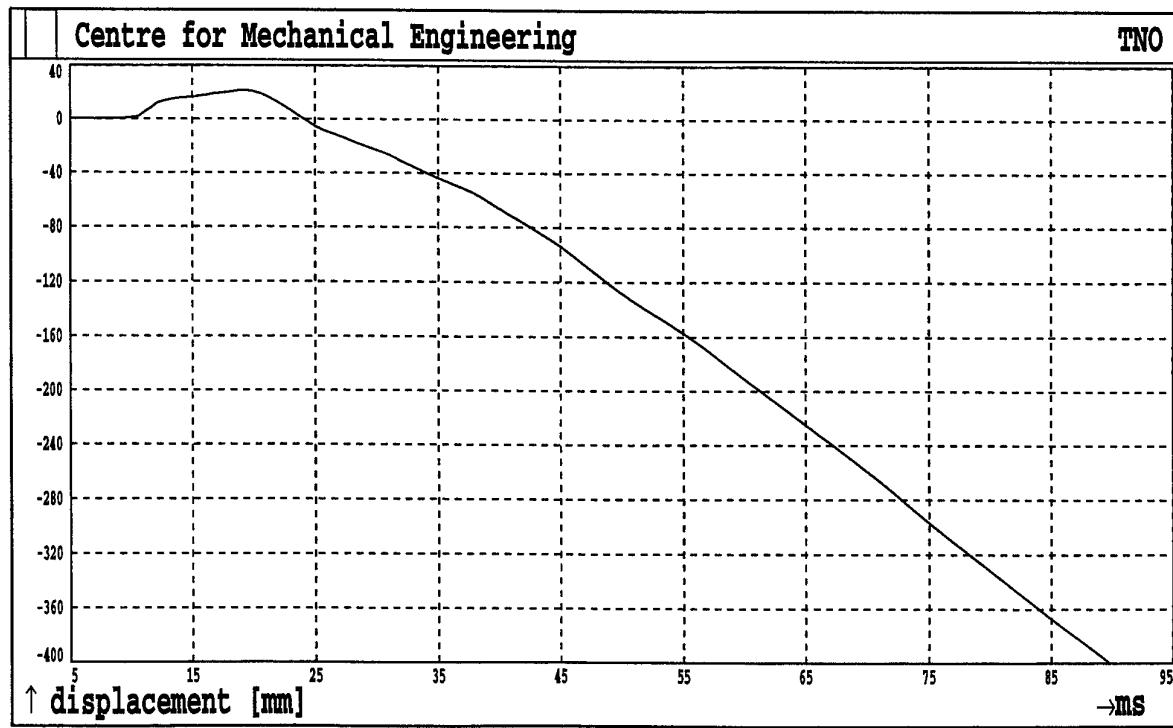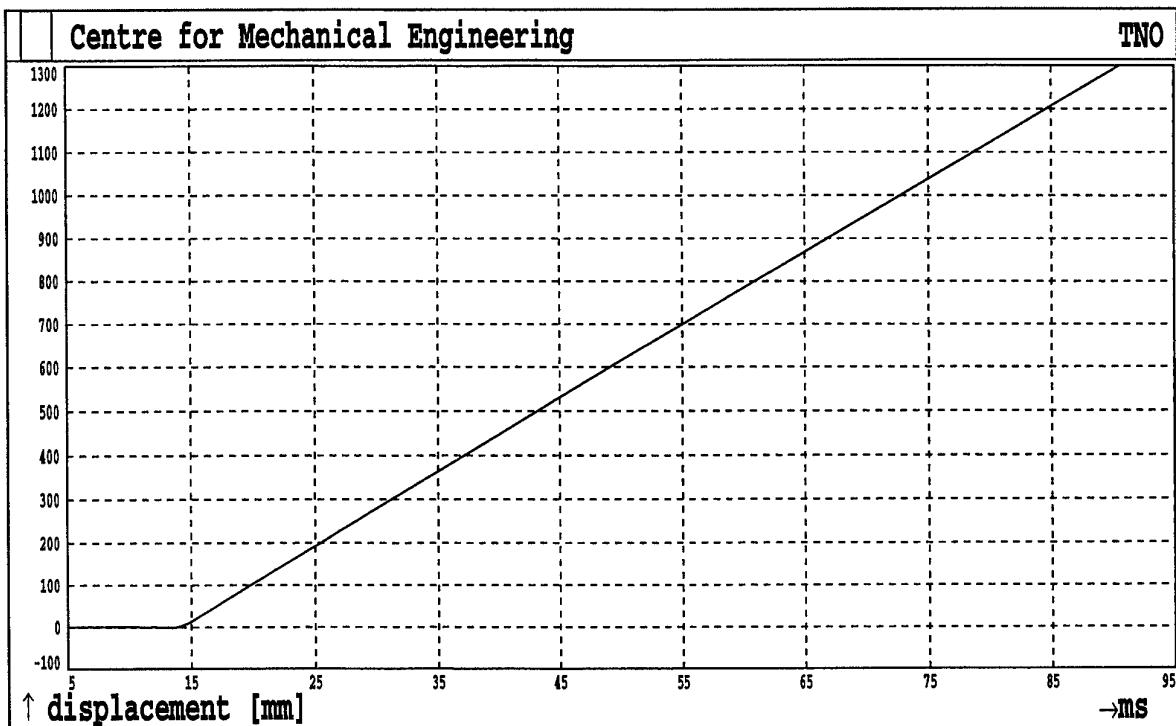
Fig.359. Shot 6   Sensor A11

Fig.360. Shot 6   Sensor A12
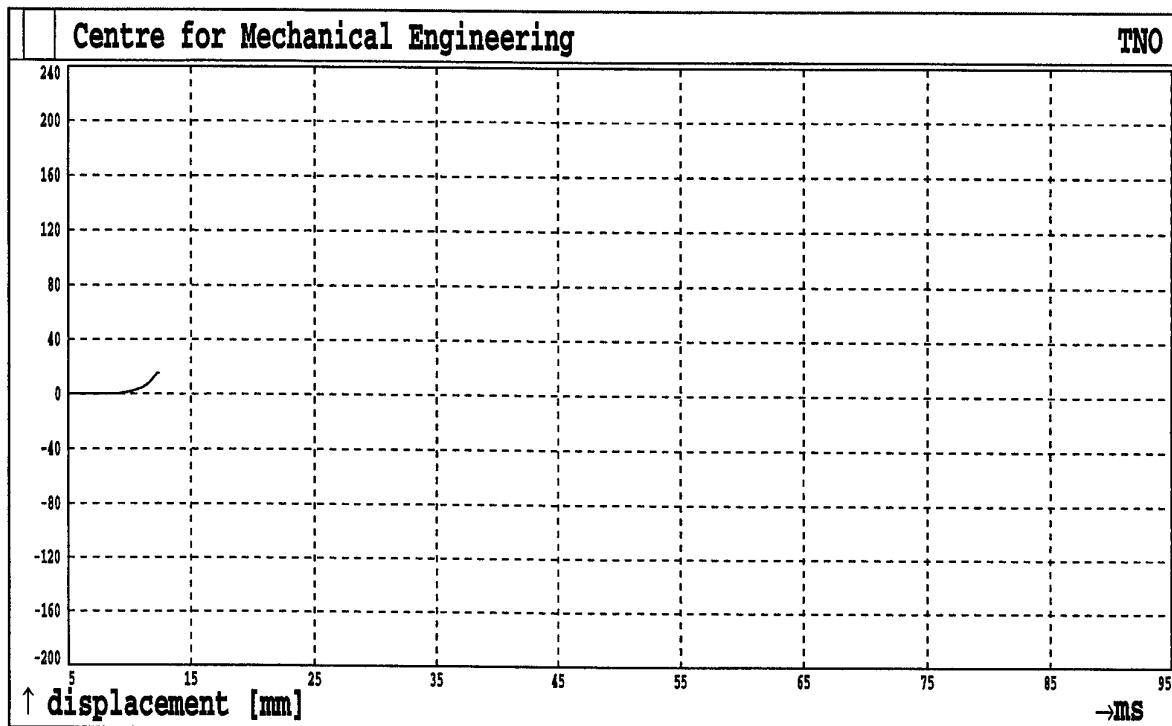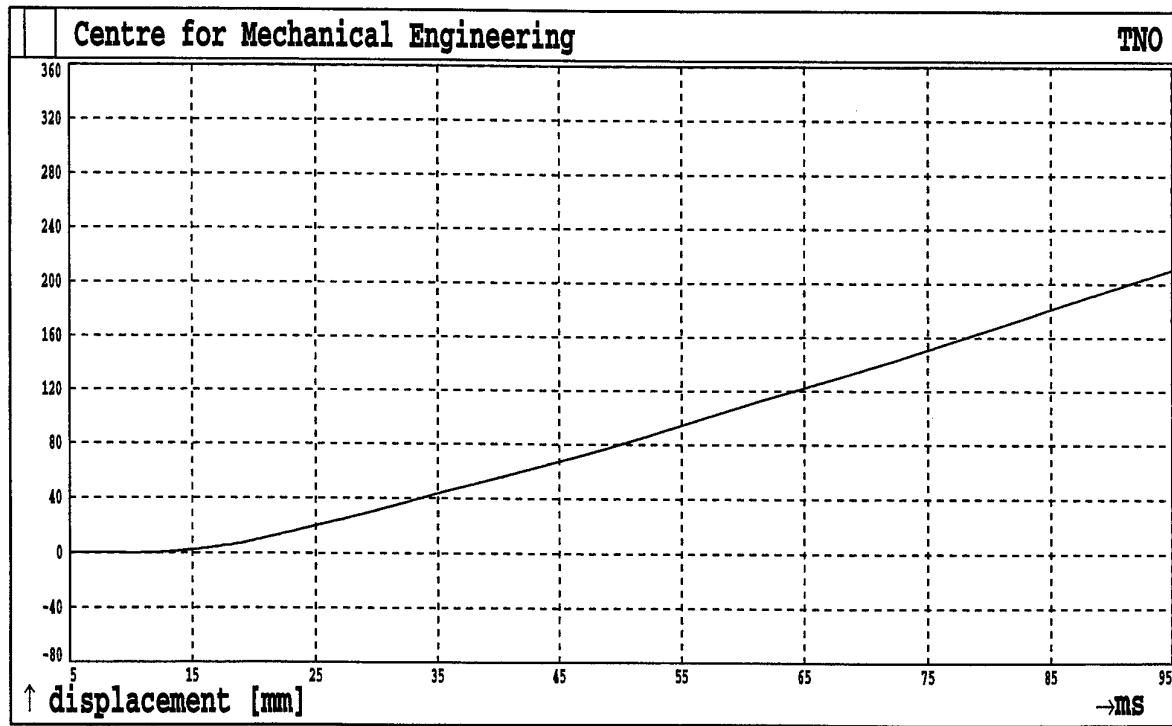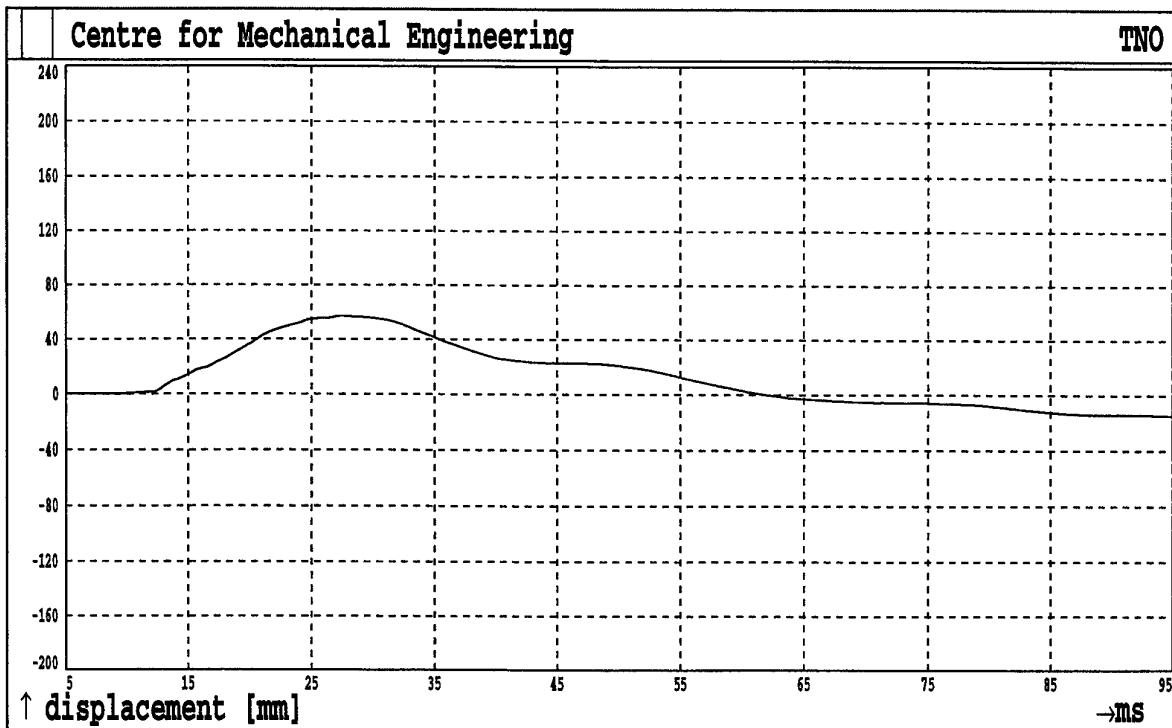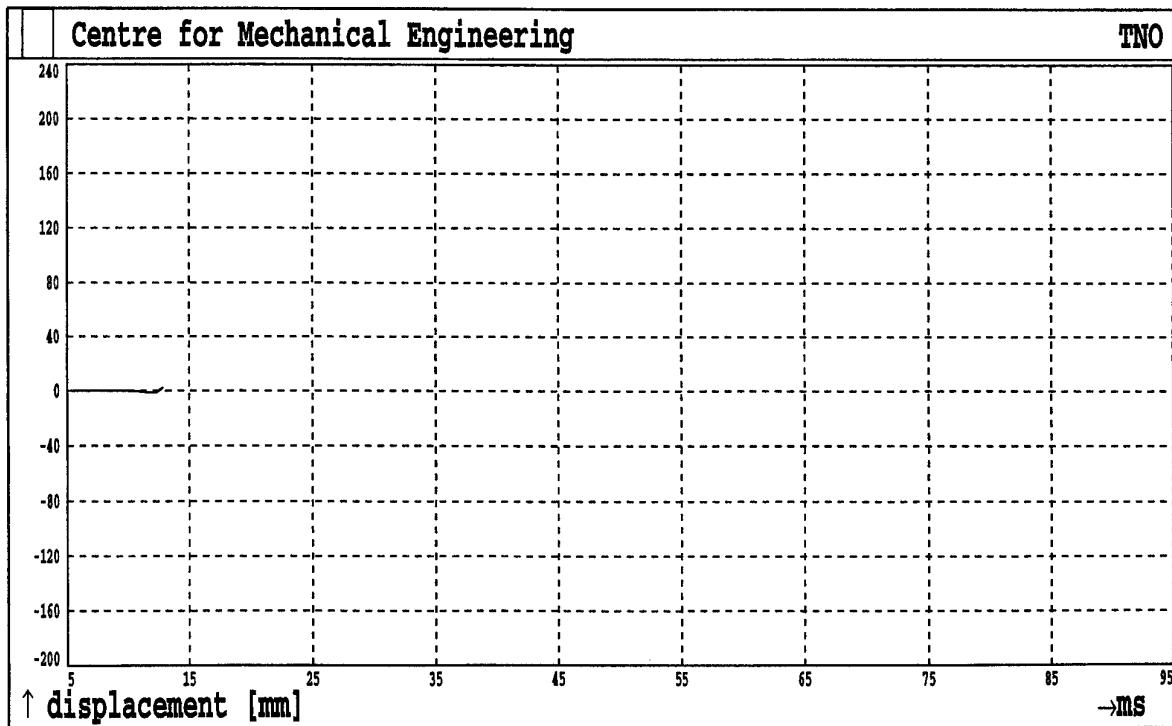
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↑ displacement [mm]   →ms

Fig.361. Shot 6   Sensor A13

Centre for Mechanical Engineering   **TNO**

↑ displacement [mm]   →ms

Fig.362. Shot 6   Sensor A14

Centre for Mechanical Engineering   TNO

↑ displacement [mm]   →ms

Fig.363. Shot 6   Sensor A15

Centre for Mechanical Engineering   TNO

↑ displacement [mm]   →ms

Fig.364. Shot 6   Sensor A16

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Fig.365. Shot 6   Sensor A17

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Fig.366. Shot 6   Sensor A22

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Fig.367. Shot 6   Sensor A25

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Fig.368. Shot 6   Sensor A26

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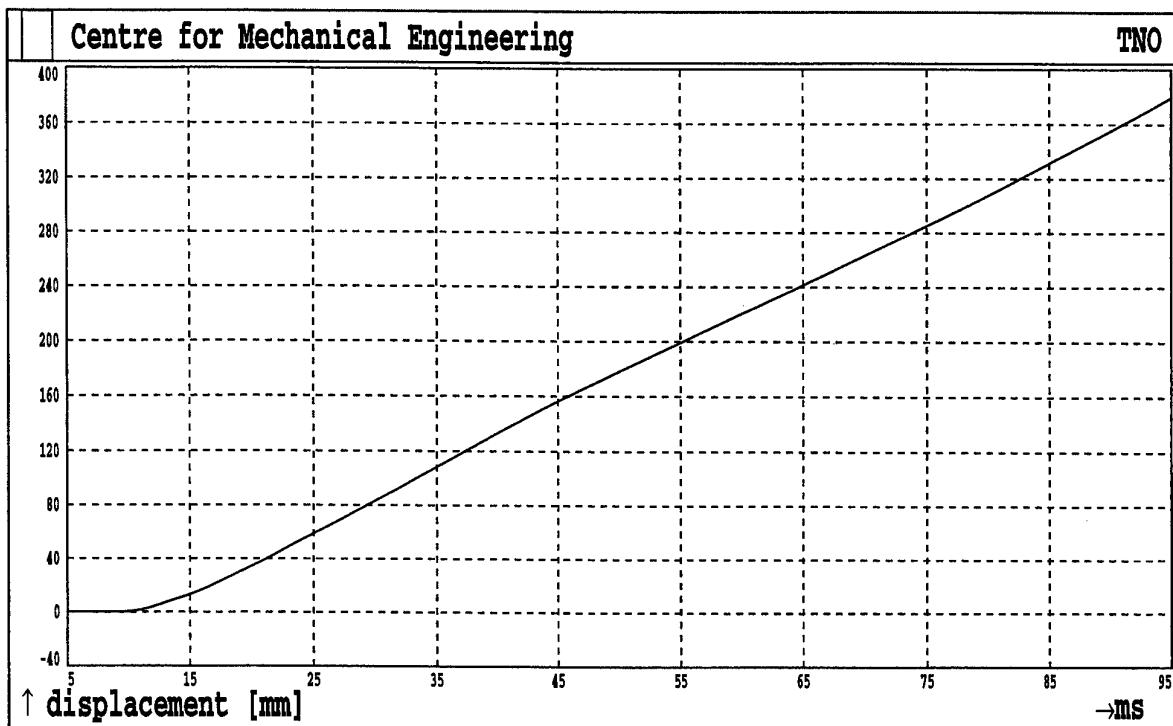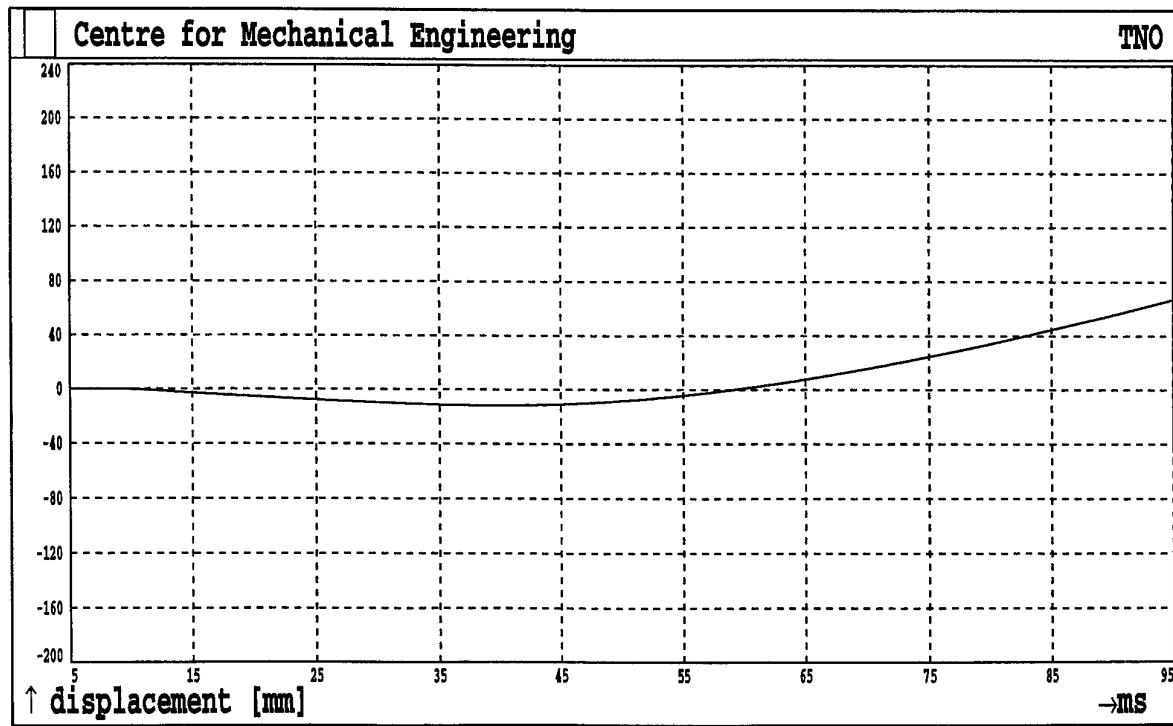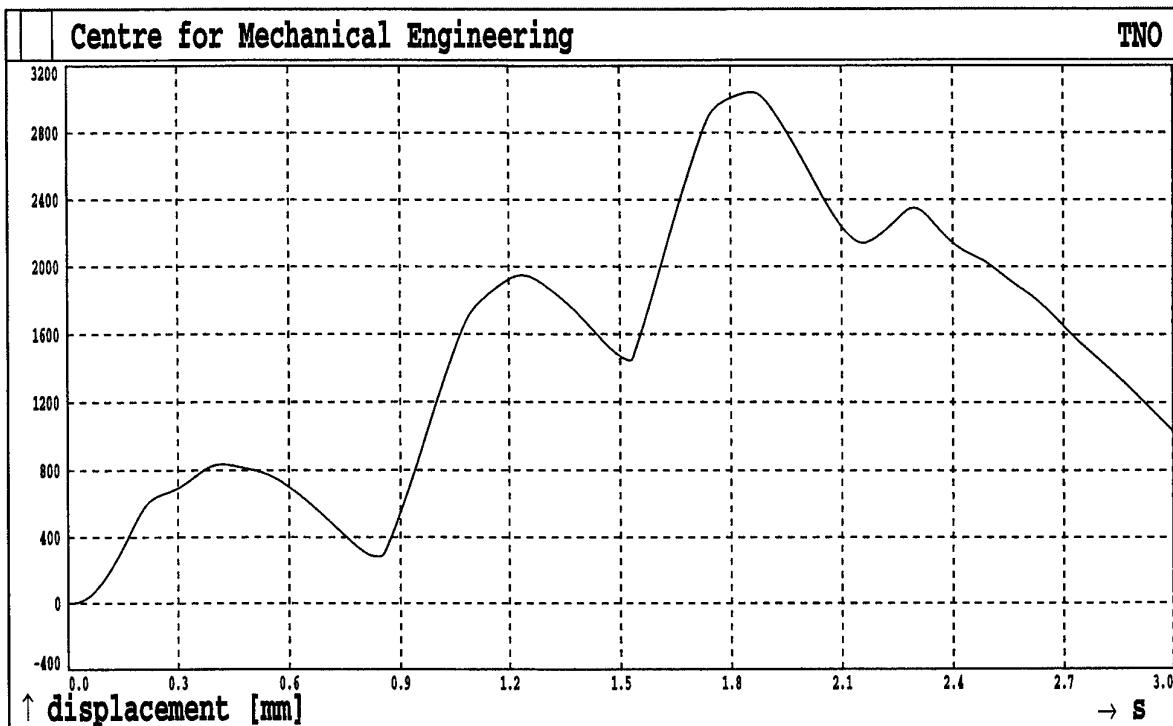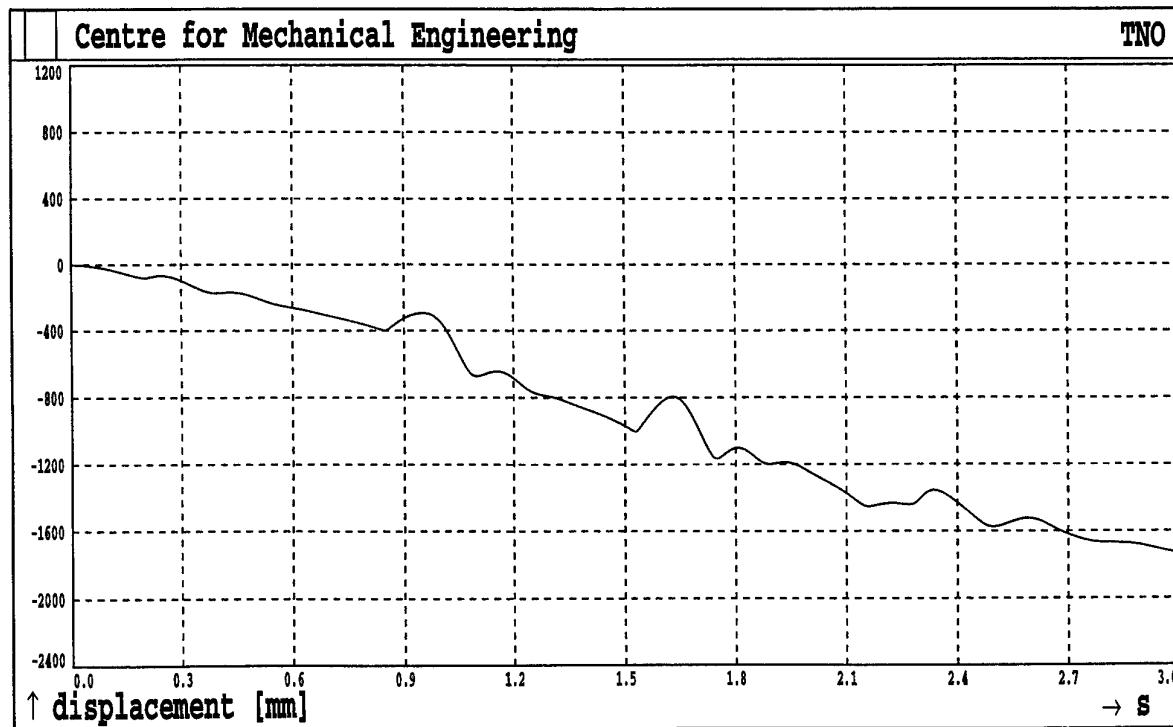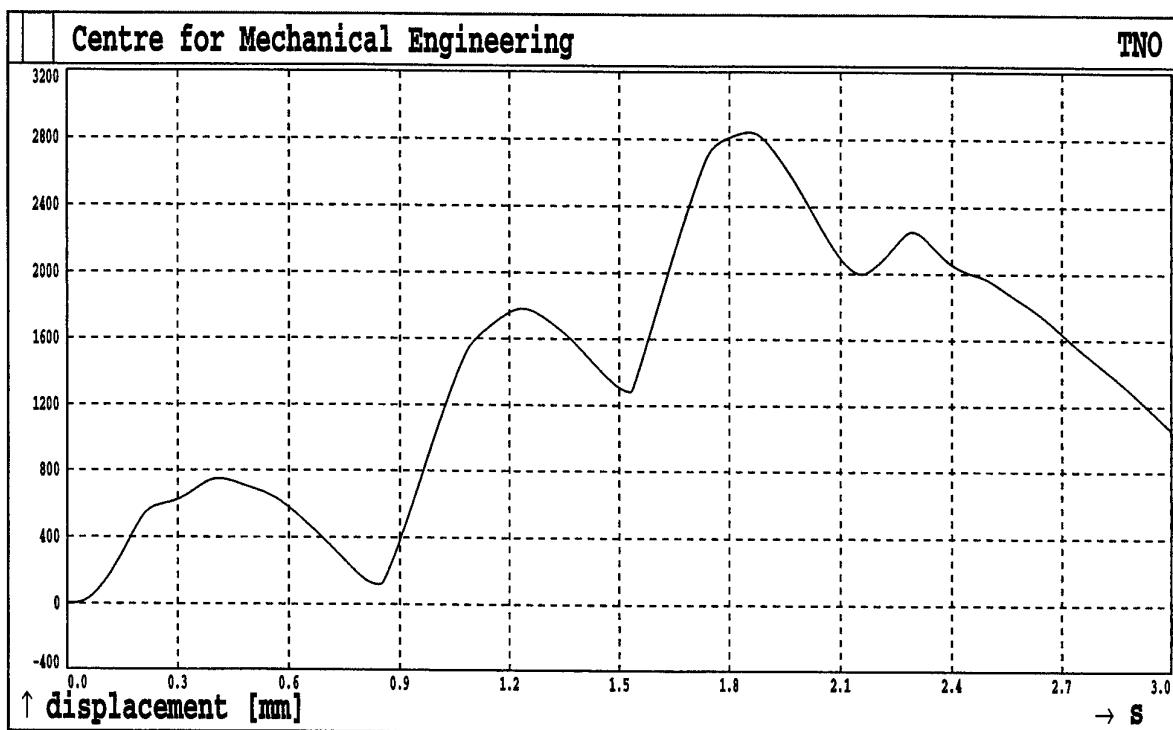
Fig.369. Shot 6 Sensor A27

Fig.370. Shot 6 Sensor A28

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↑ displacement [mm]   → s
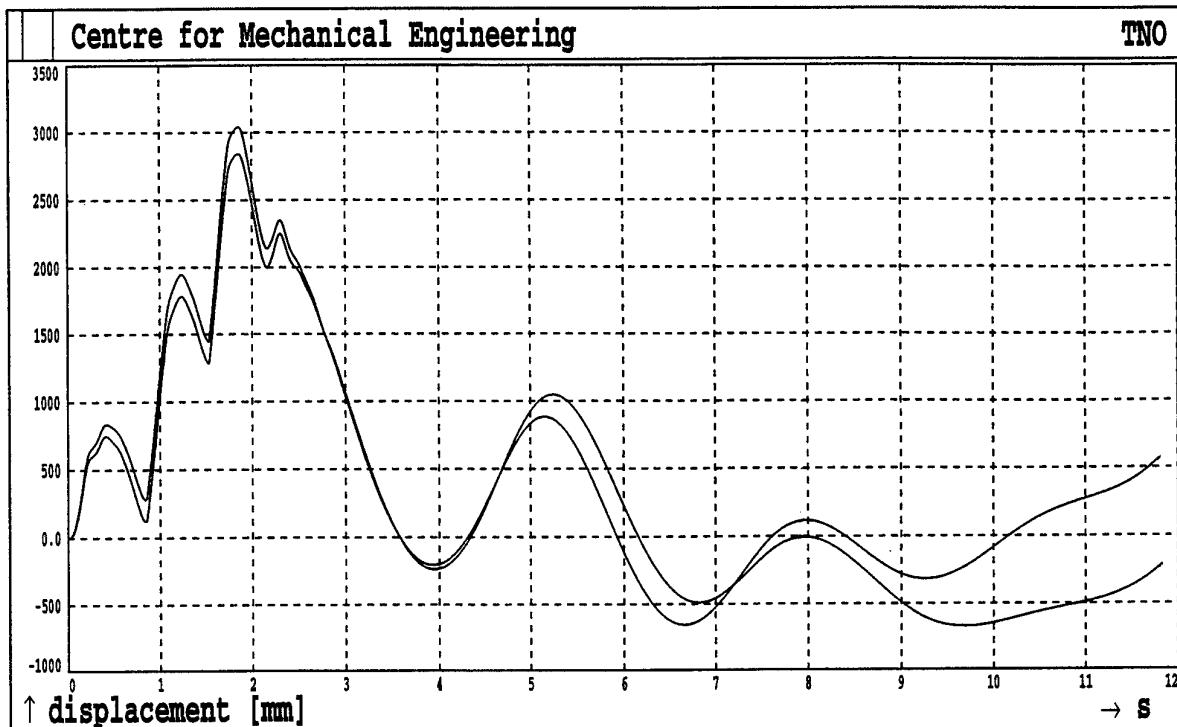
Fig.371. Shot 6   Sensor A25 and sensor A27

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↑ displacement [mm]   → s
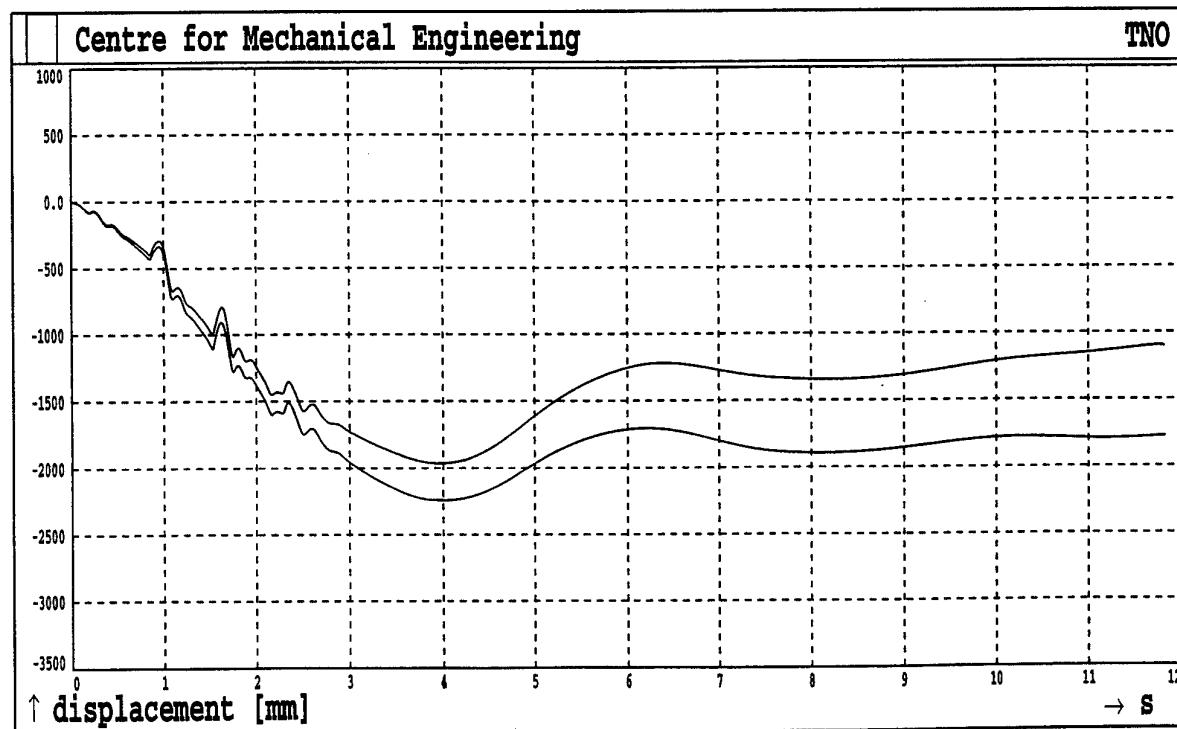
Fig.372. Shot 6   Sensor A26 and sensor A28
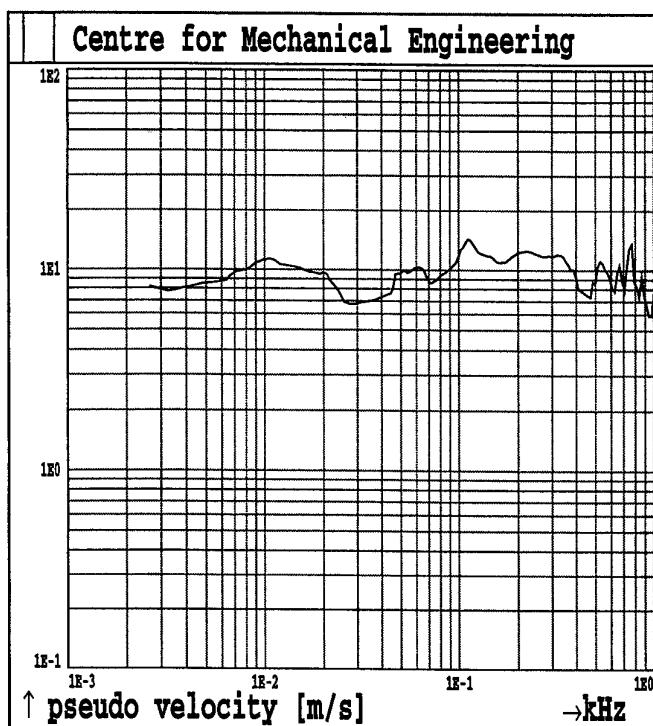
Fig.373. Shot 6 MAXIMAX Sensor A5
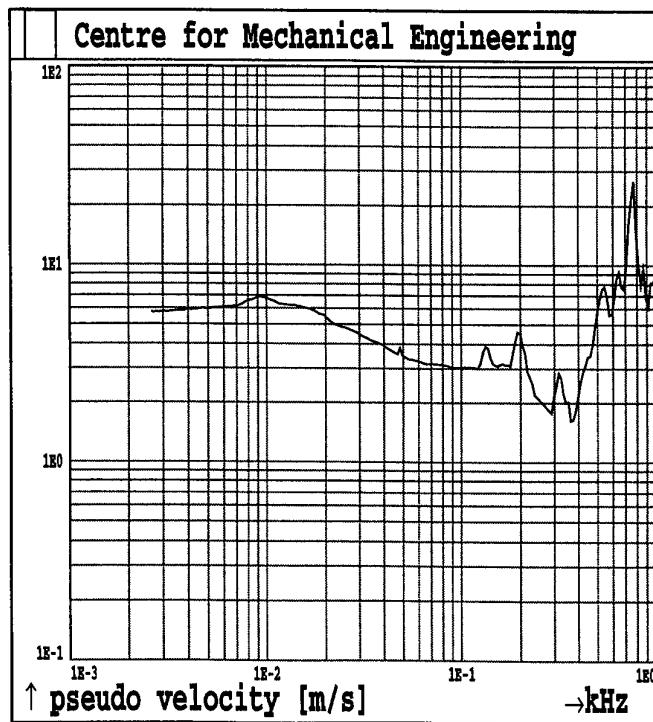
Fig.374. Shot 6 Sensor A6; SRS calculated
         only over the first 220 ms signal

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↑ pseudo velocity [m/s]   →kHz
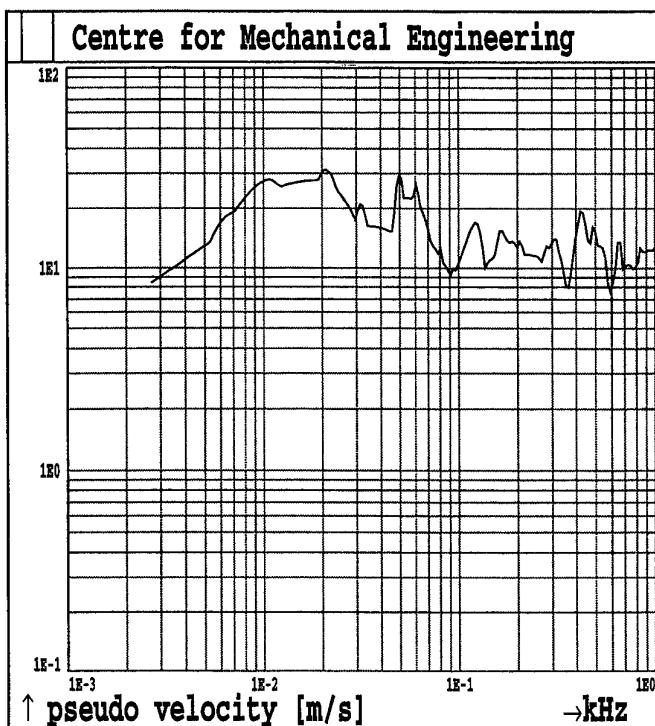
Fig.375. Shot 6 MAXIMAX Sensor A8

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↑ pseudo velocity [m/s]   →kHz
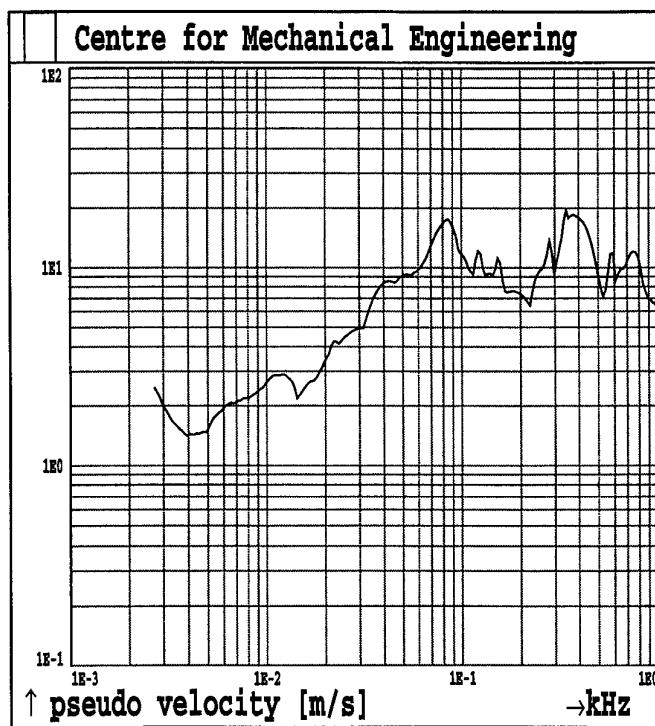
Fig.376. Shot 6 MAXIMAX Sensor A9

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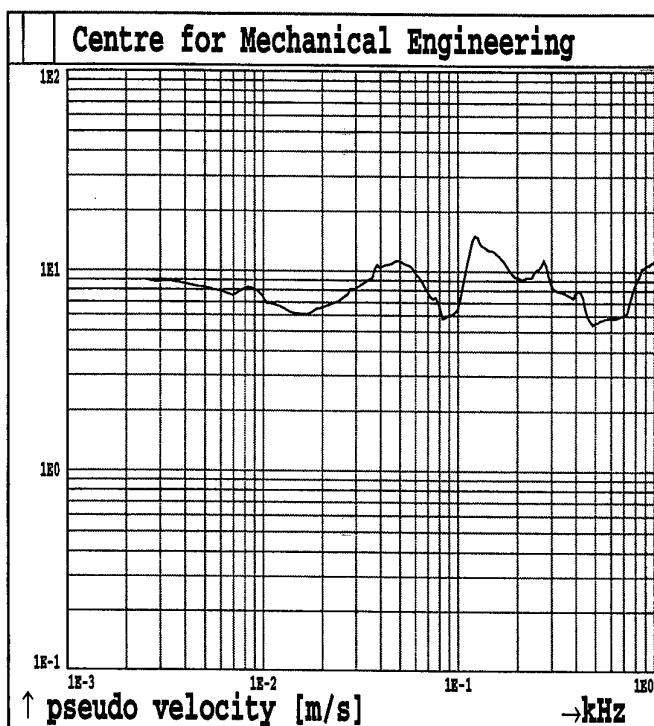
Fig.377. Shot 6 MAXIMAX Sensor A10
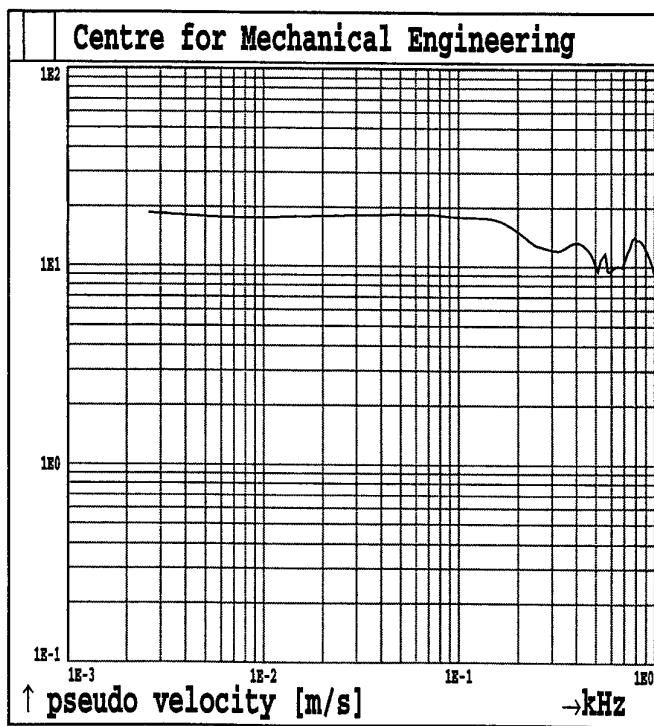
Fig.378. Shot 6 MAXIMAX Sensor A11

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↑ pseudo velocity [m/s]   →kHz
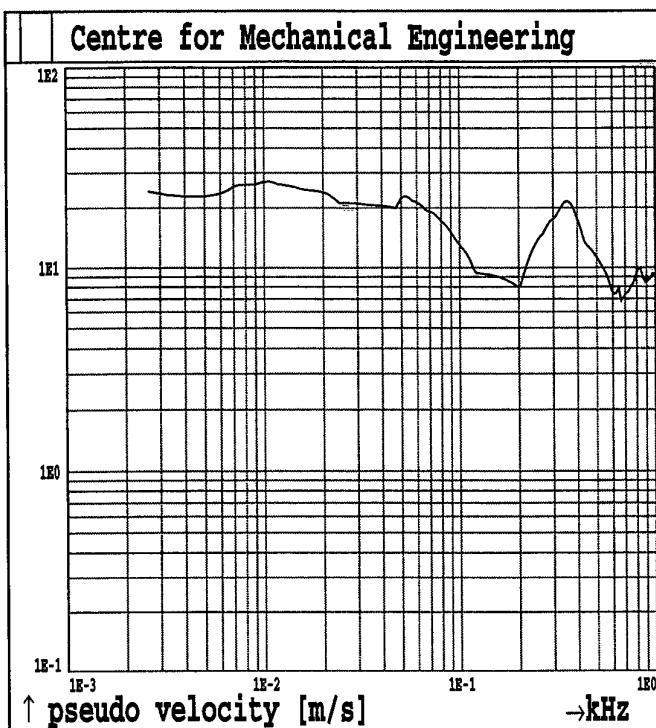
Fig.379. Shot 6 MAXIMAX Sensor A12

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↑ pseudo velocity [m/s]   →kHz
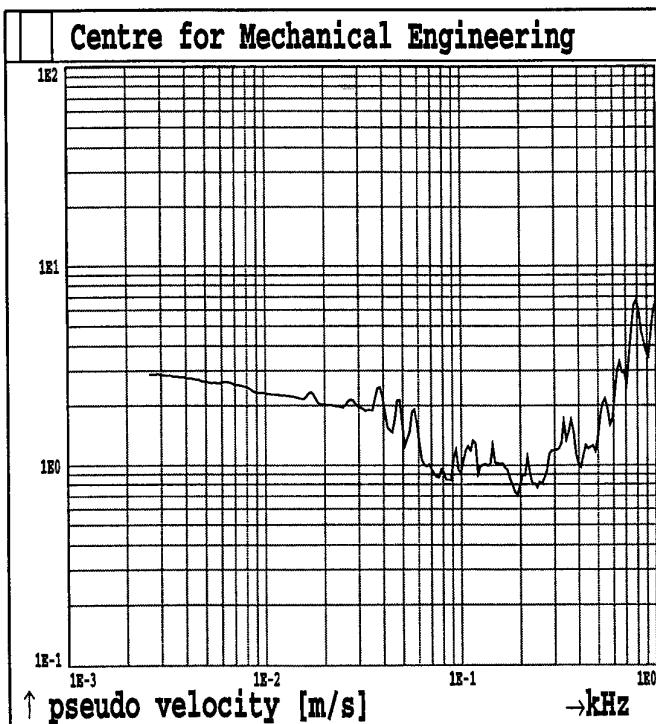
Fig.380. Shot 6 MAXIMAX Sensor A14

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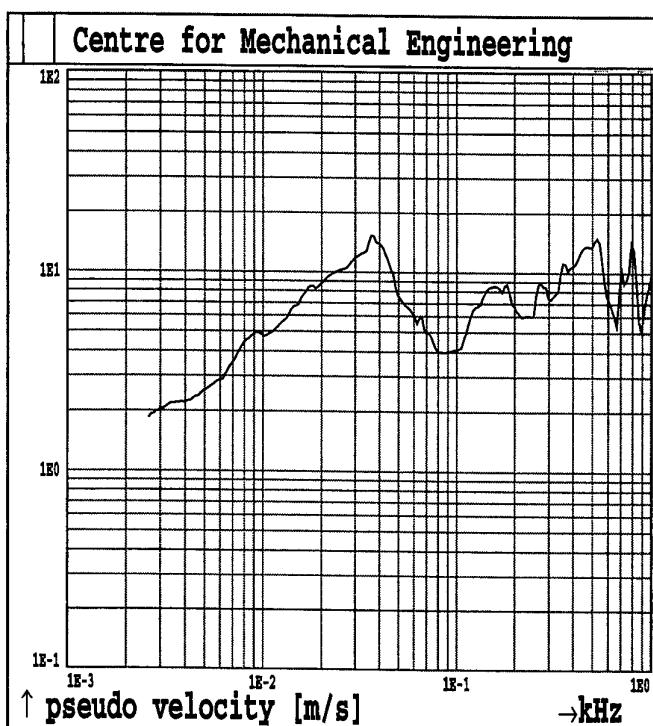
Fig.381. Shot 6 MAXIMAX Sensor A15
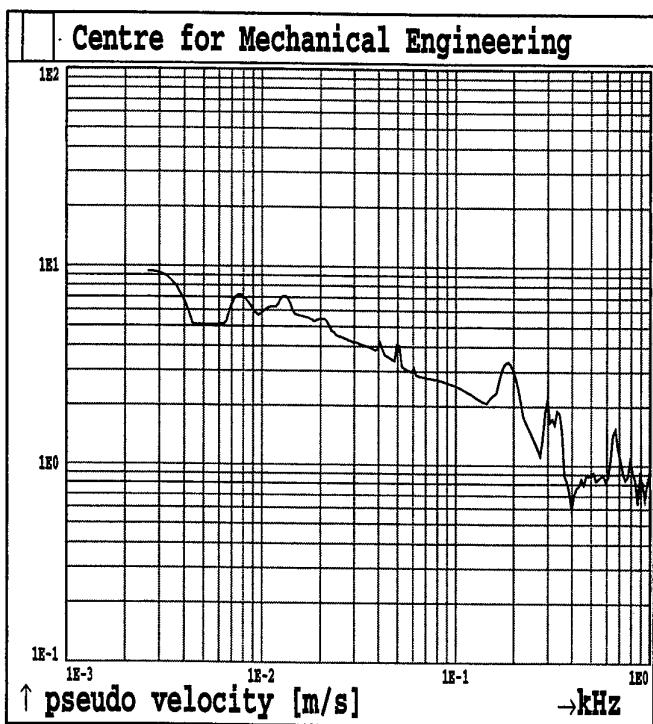
Fig.382. Shot 6 MAXIMAX Sensor A17

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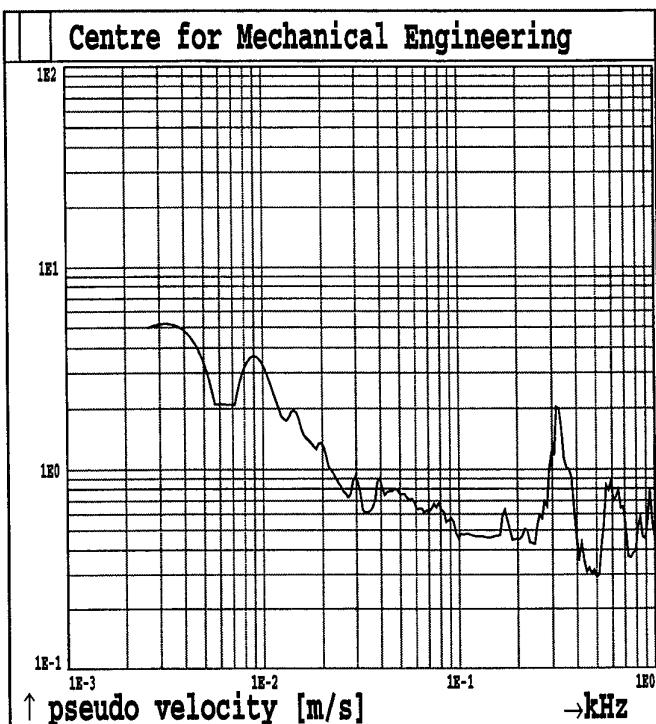
Fig.383. Shot 6 MAXIMAX Sensor A22
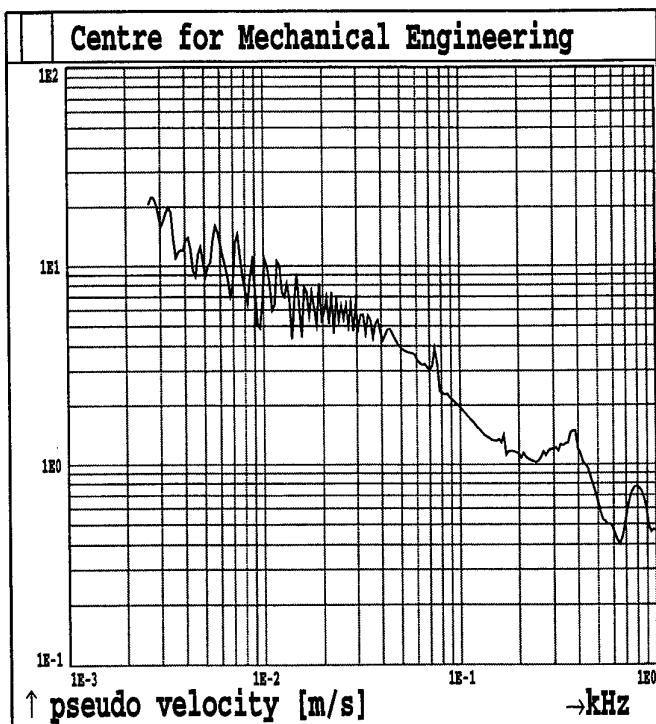
Fig.384. Shot 6 MAXIMAX Sensor A25
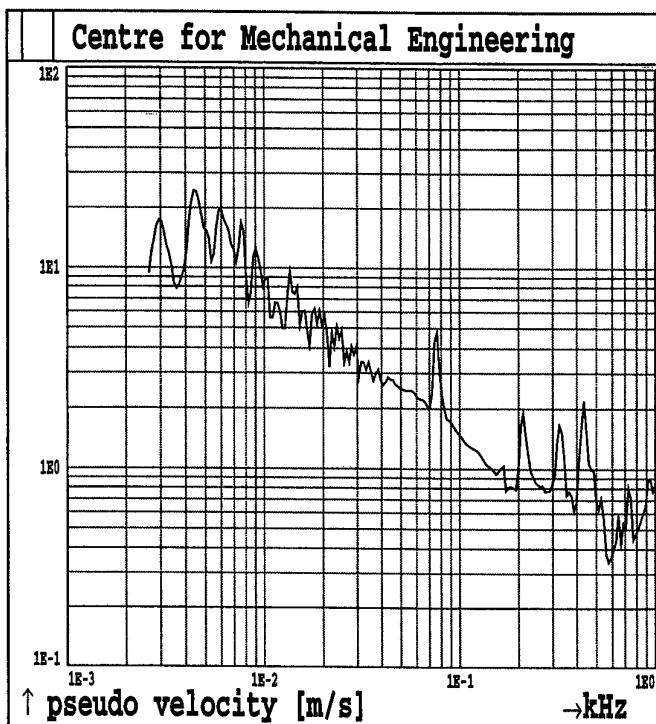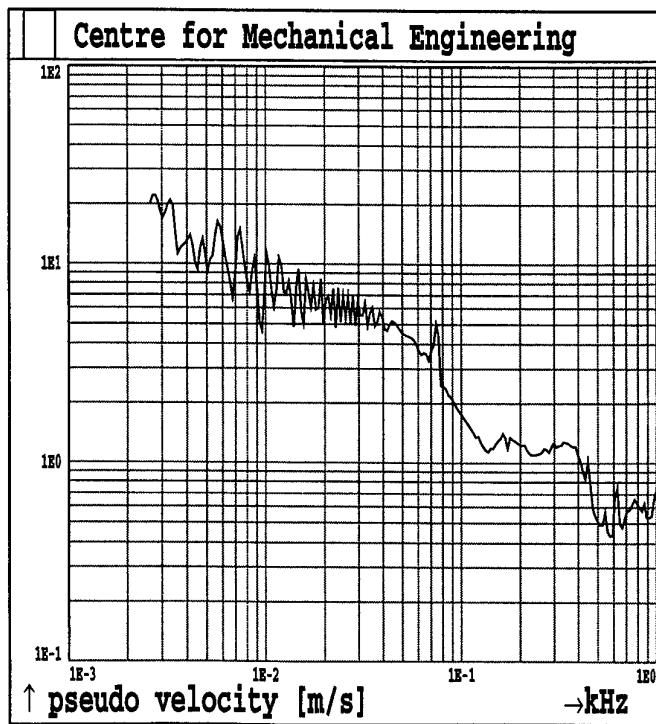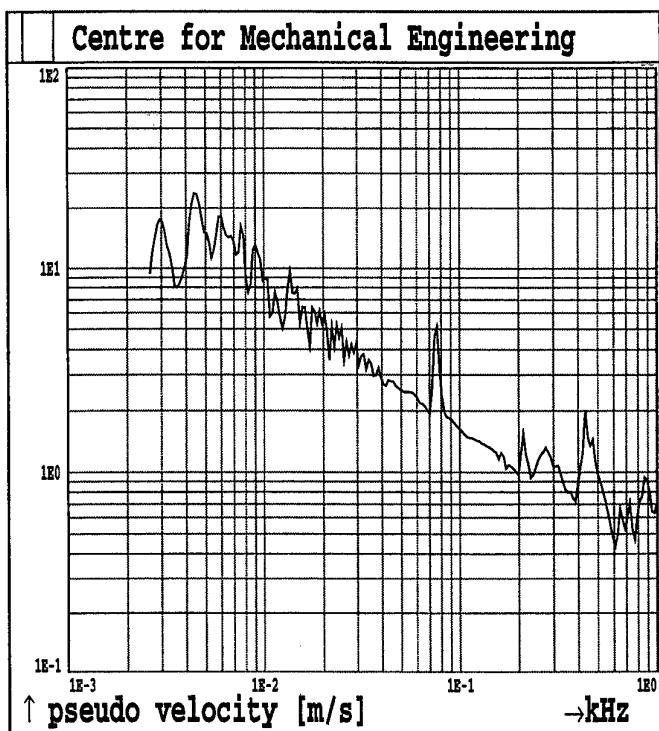
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↑ pseudo velocity [m/s]   →kHz

Fig.385. Shot 6 MAXIMAX Sensor A26

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↑ pseudo velocity [m/s]   →kHz

Fig.386. Shot 6 MAXIMAX Sensor A27

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Fig.387. Shot 6 MAXIMAX Sensor A28

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↑ displacement [mm]   →ms

Fig.388. Shot 6   Sensor R1

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↑ displacement [mm]   →ms

Fig.389. Shot 6   Sensor R2

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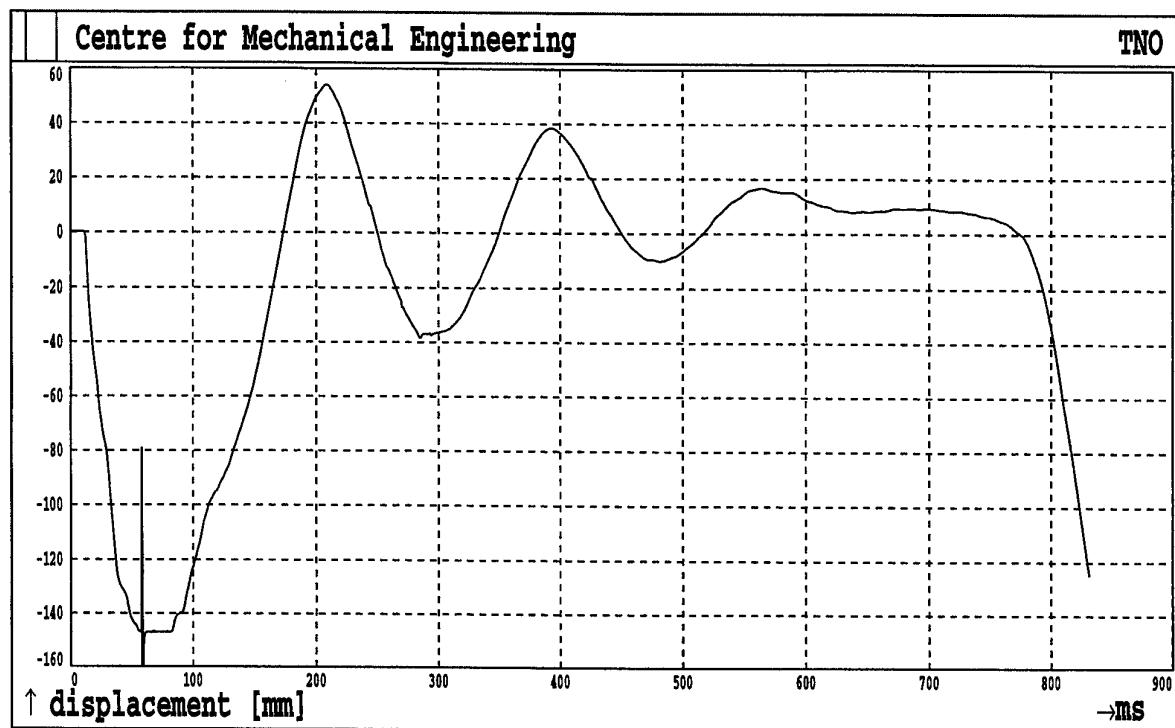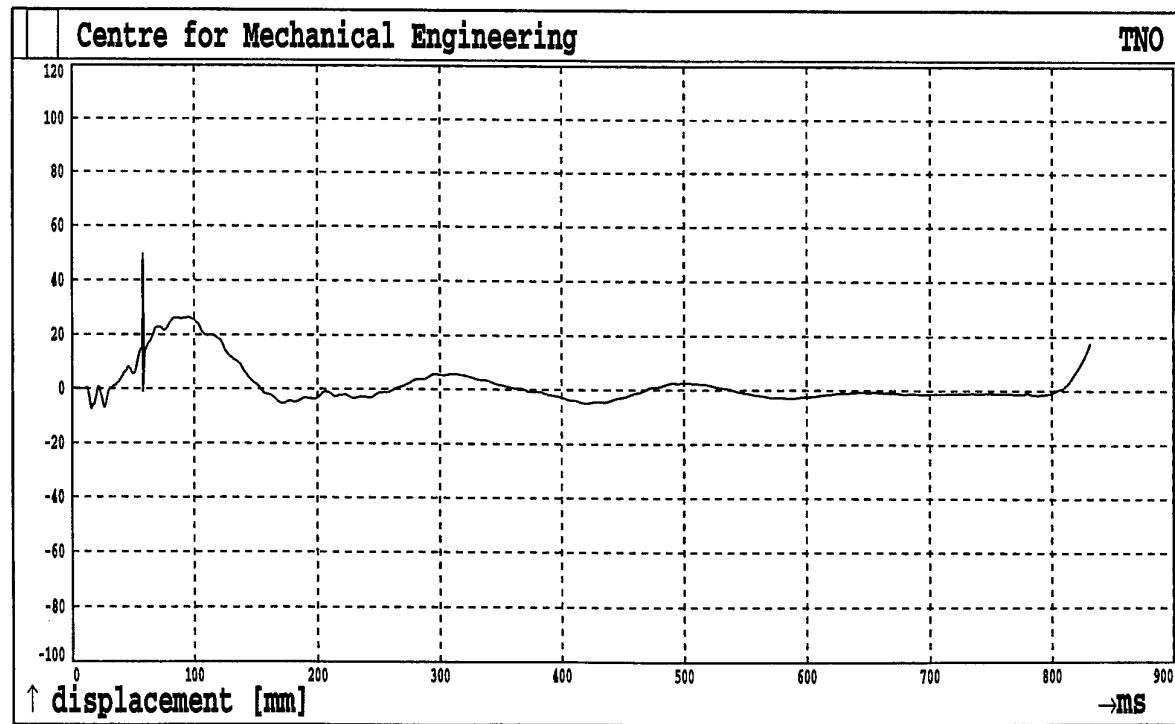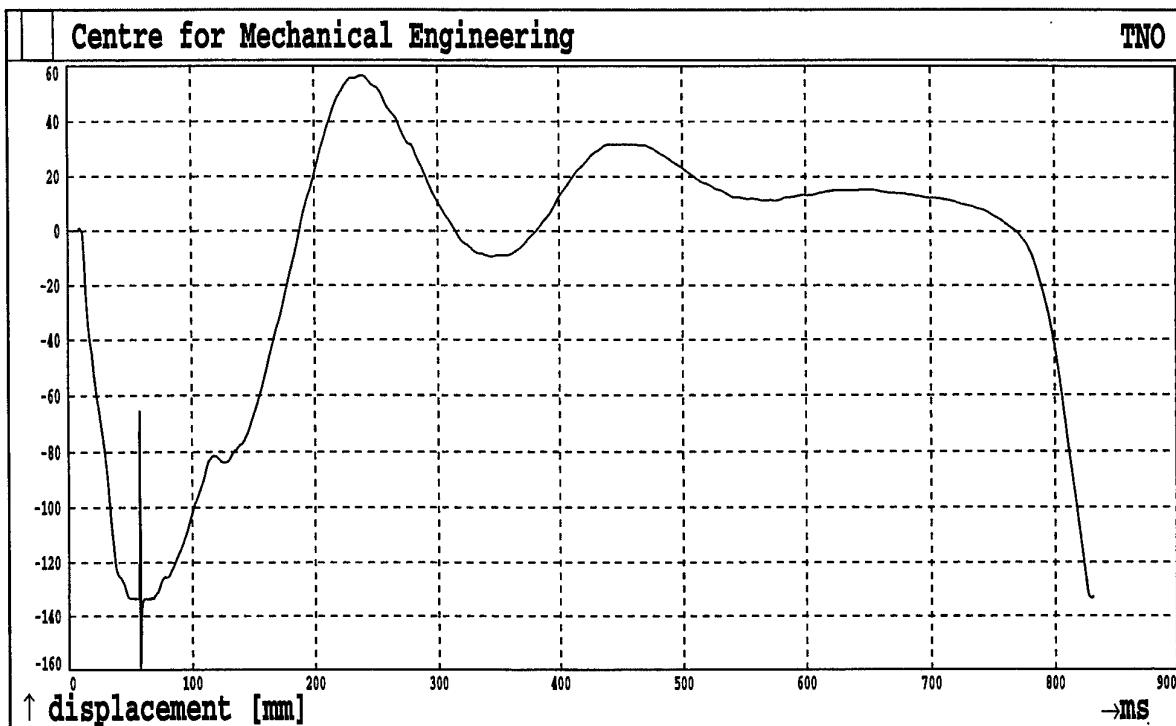
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Fig.390. Shot 6 Sensor R3

Fig.391. Shot 6 Sensor R4

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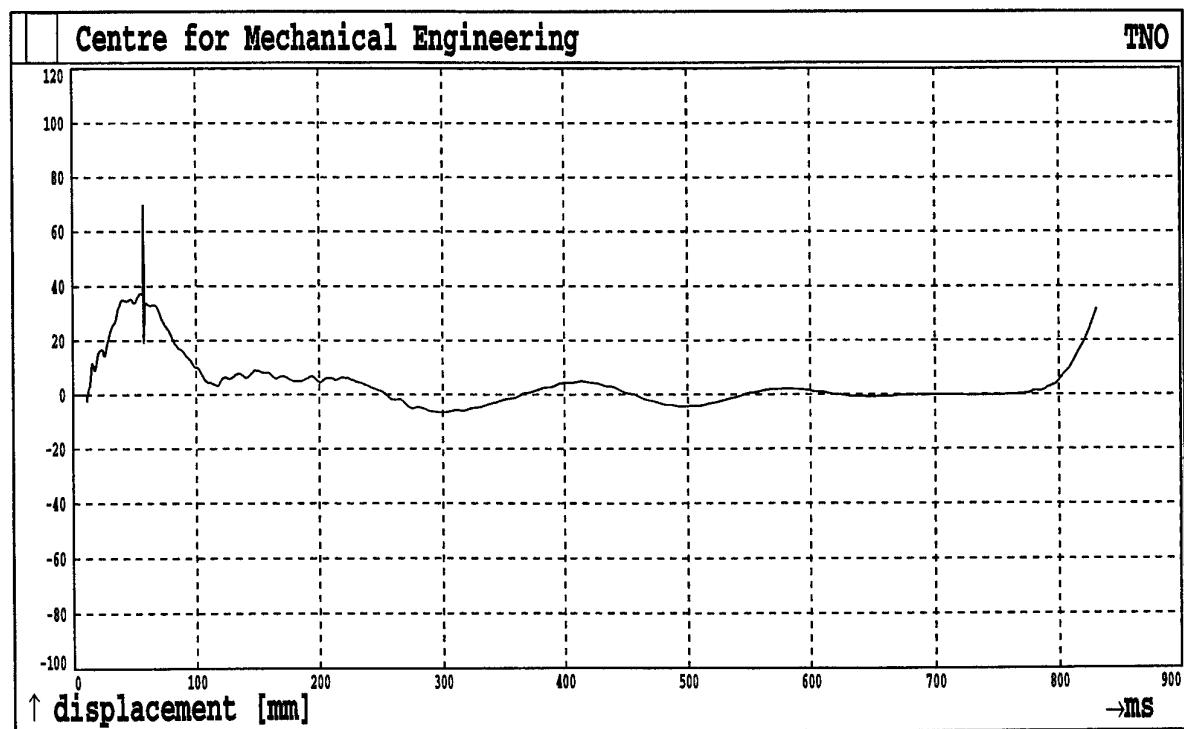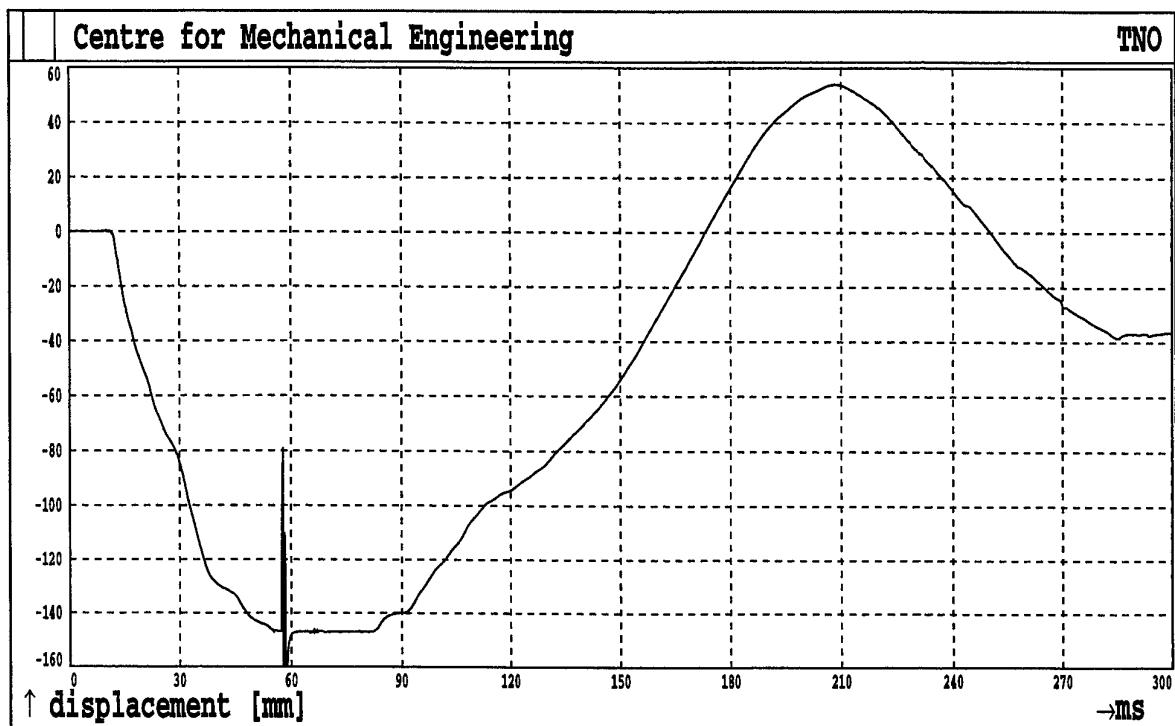
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Fig.392. Shot 6   Sensor R1

Fig.393. Shot 6   Sensor R2

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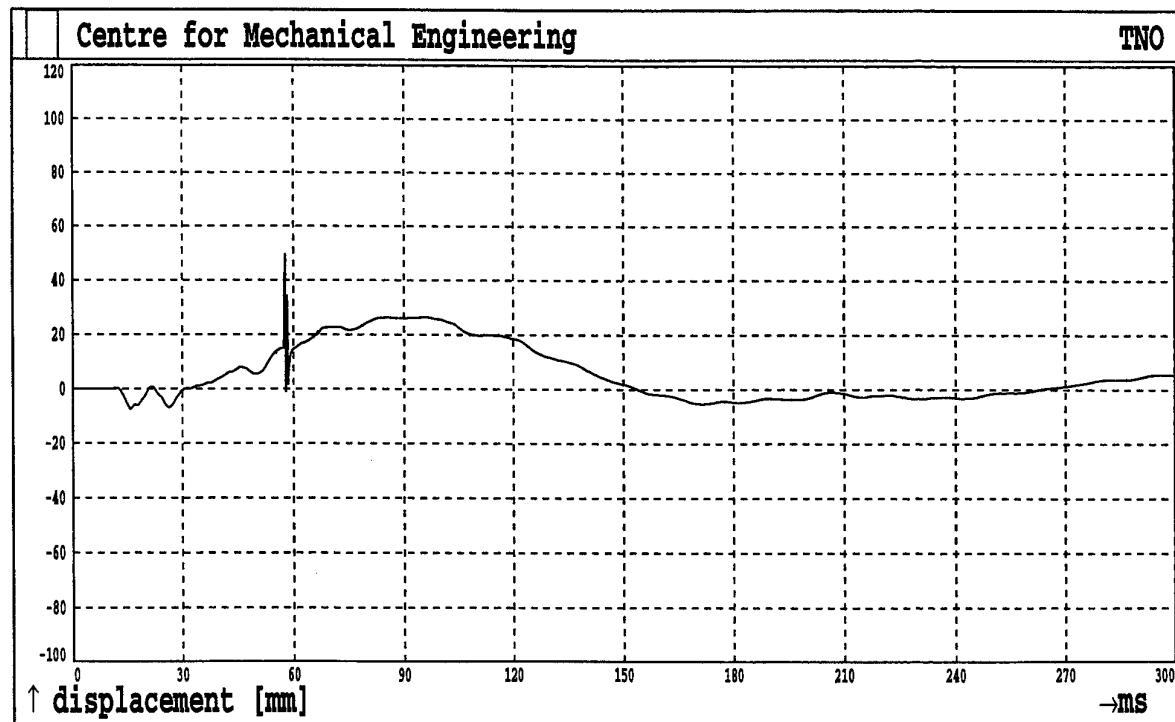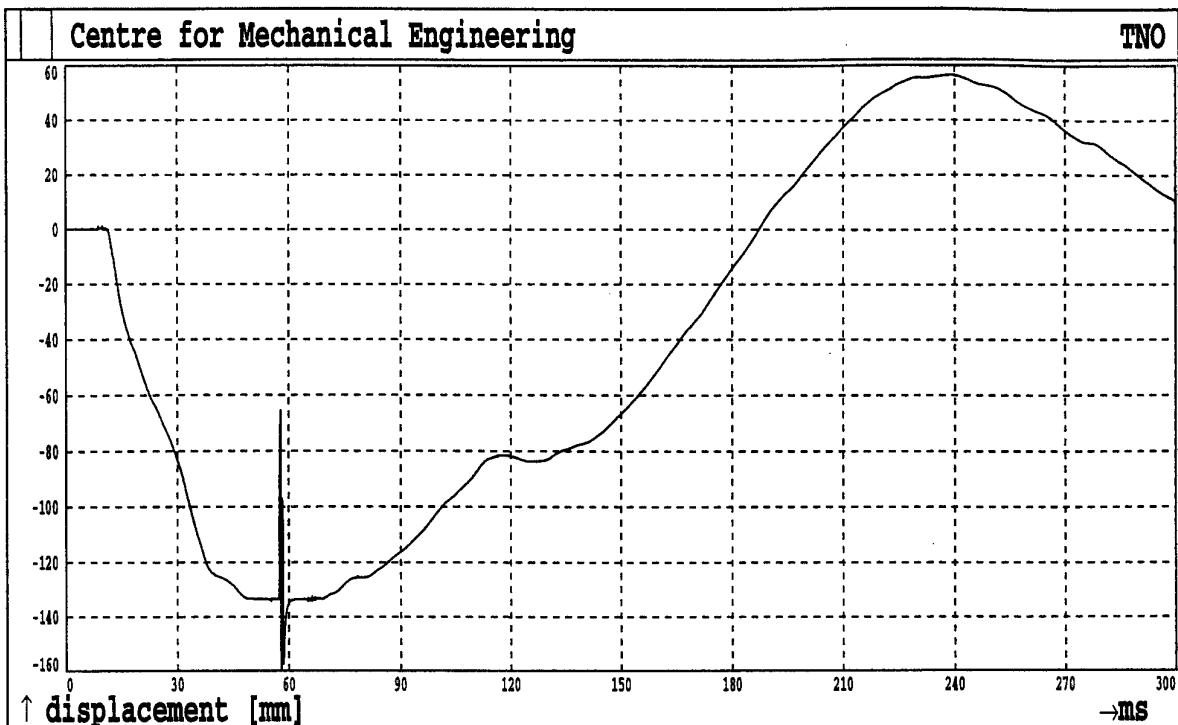
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Fig.394. Shot 6   Sensor R3
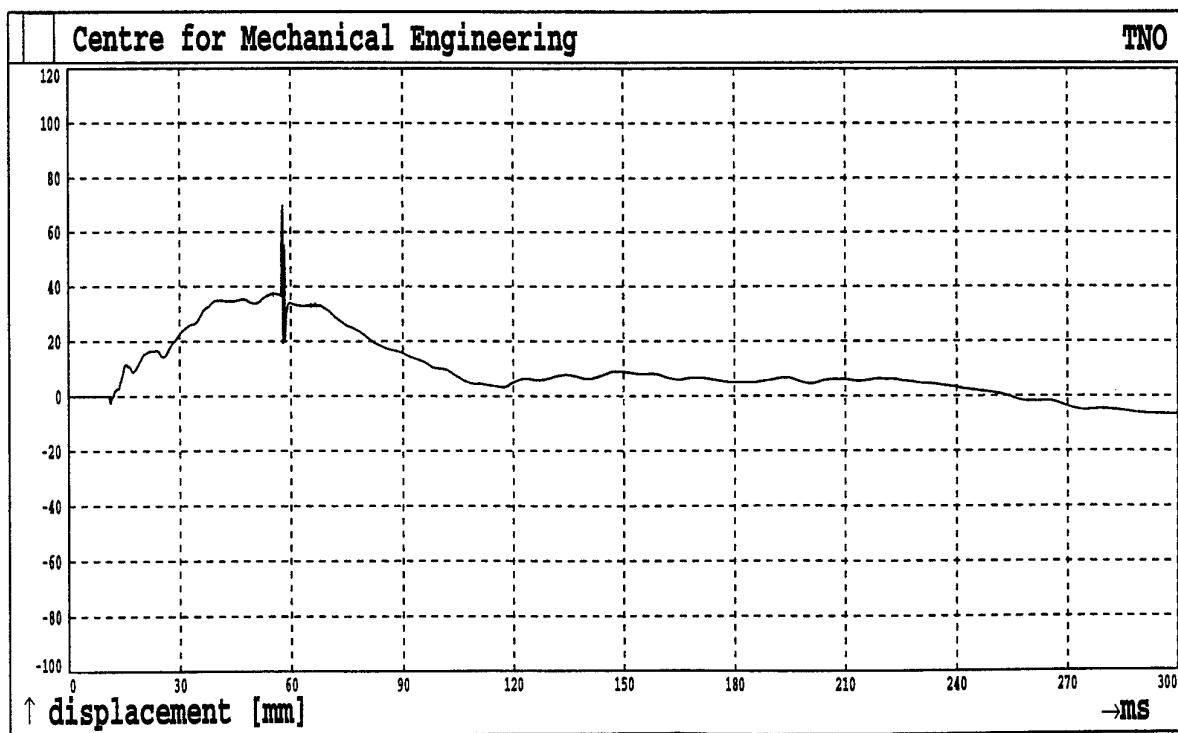
Fig.395. Shot 6   Sensor R4

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11. AUTHOR(S) B. Bosman

12. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Centre for Mechanical Engineering Leeghwaterstraat 5 2628 CA DELFT, The Netherlands

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15. ABSTRACT (MAXIMUM 200 WORDS, 1044 BYTES)

In the scope of the development of the Trojka drone a test structure has been subjected to 2 series of 3 underwater shock loads of increasing shock levels.
During these tests TNO carried out measurements with 24 strain gauges, 28 accelerometers, 4 relative displacement transducers and 2 pressure transducers.
This report presents the measured pressure signals, strain signals, relative displacements, accelerations, the calculated maximax shock response spectra (at 1 % damping) and, by integration of the accelerations, velocities and displacements, of the second series of 3 measurements.

16. DESCRIPTORS Underwater explosion Ship structure Shock response	IDENTIFIERS Shock measurements shock mounting

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